L Number	Hits	Search Text	DB	Time stamp
-	1	("5974144").PN.	USPAT	2004/02/02 15:11
-	111	(713/166).CCLS.	USPAT	2004/01/30 16:22
-	1812	((open unlock) with partition) and ((close lock) with partition)	USPAT	2004/02/02 15:12
-	15	((open unlock) with partition) and ((close lock) with partition) and secure and private	USPAT	2004/02/02 15:27
-	328	((open unlock) with partition) and ((close lock) with partition) and (secure private) and @ad<=20000630	USPAT	2004/02/02 15:28

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United States Patent [19]

Jones et al.

[11] Patent Number: 5,623,637

[45] Date f Patent: Apr. 22, 1997

[54] **ENCRYPTED DATA STORAGE CARD INCLUDING SMARTCARD INTEGRATED CIRCUIT FOR STORING AN ACCESS PASSWORD AND ENCRYPTION KEYS**

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[73] Assignee: **Telequip Corporation**, Hollis, N.H.

[21] Appl. No.: **651,205**

[22] Filed: **May 17, 1996**

Related U.S. Application Data

[63] Continuation of Ser. No. 161,854, Dec. 6, 1993, abandoned.

[51] **Int. Cl.**[6] **G06F 12/14**

[52] **U.S. Cl.** **395/491**; 395/430; 395/442; 395/833; 395/188.01; 380/23; 380/25

[58] **Field of Search** 380/23, 25, 4; 395/188.01, 430, 442, 490, 491

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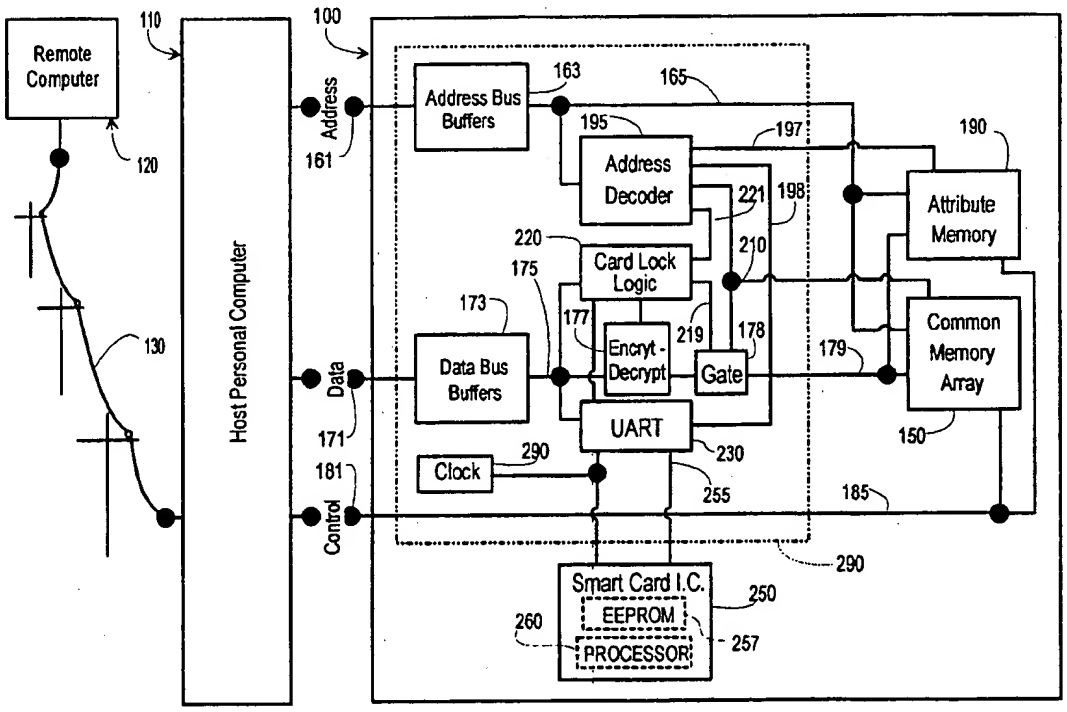
Attorney, Agent, or Firm—Banner & Witcoff, Ltd.

[57] **ABSTRACT**

A detachable PCMCIA memory card incorporating a smartcard integrated circuit for storing a password value and logic circuitry for preventing access to information stored on the memory card unless the user of the host computer to which the memory card is connected can supply a password matching the stored password. The smartcard integrated circuit may also be used to store public and private key values used to encrypt and decrypt data stored on the card or elsewhere on the host computer or exchanged with a remote computer.

3 Claims, 2 Drawing Sheets



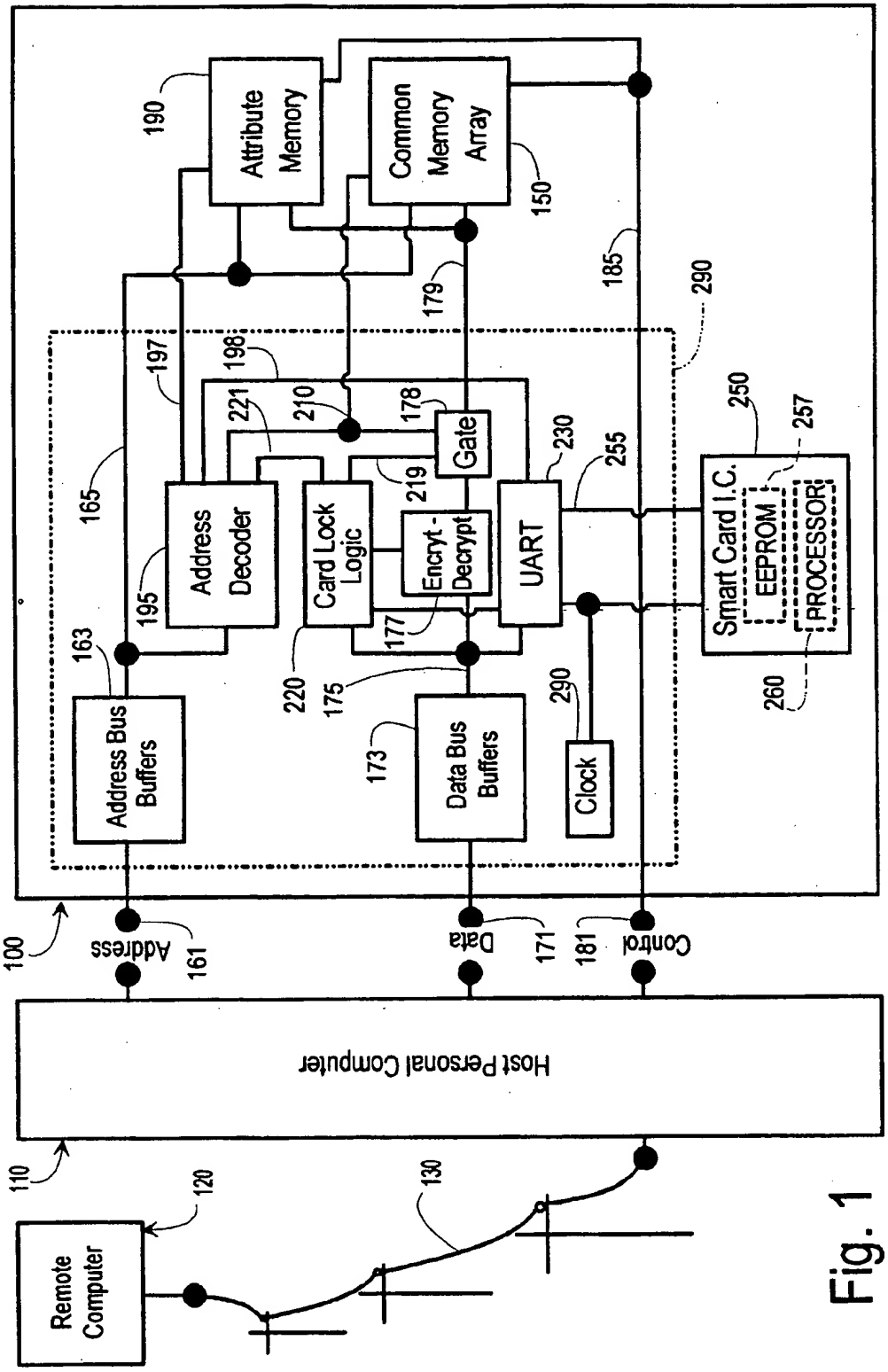

Attribute Memory
Common Memory Array
Address Decoder
Card Lock Logic
Encryt - Decrypt
UART
Gate
Smart Card I.C.
EEPROM
PROCESSOR
Address Bus Buffers
Data Bus Buffers
Clock
Address
Data
Control
Host Personal Computer
Remote Computer
100
110
120
130
150
161
163
165
171
173
175
177
178
179
181
185
190
195
197
198
210
219
220
221
230
250
255
257
260
290

Fig. 1

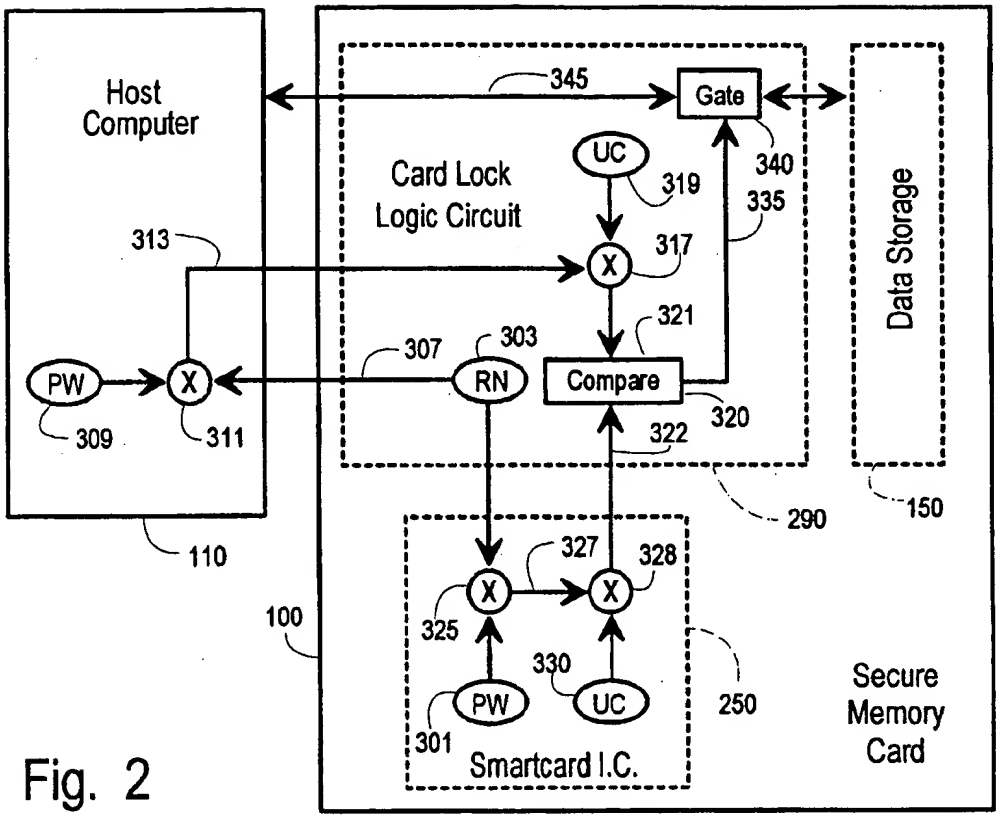

Host Computer
345
Gate
Card Lock Logic Circuit
UC
319
340
335
313
317
321
307
303
PW
RN
Compare
309
311
320
322
Data Storage
290
150
110
327
328
325
100
330
250
PW
UC
301
Smartcard I.C.
Secure Memory Card

Fig. 2

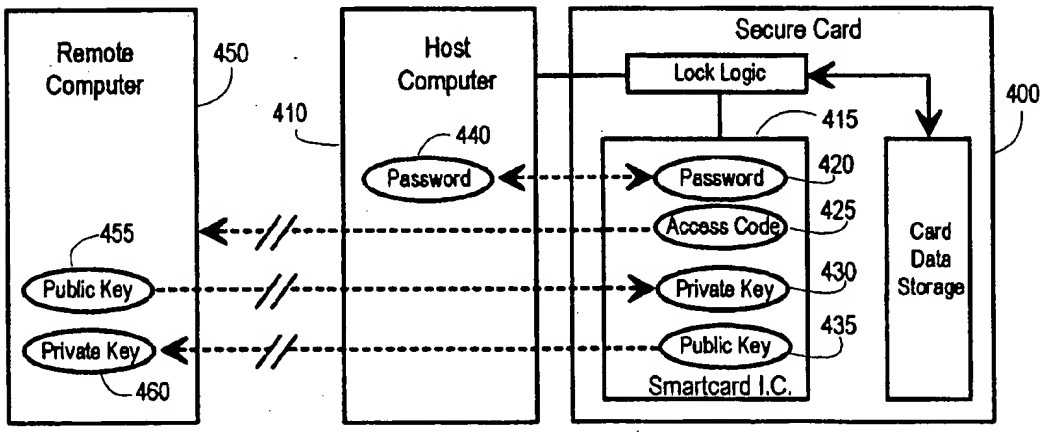

Remote Computer
450
Host Computer
Secure Card
Lock Logic
400
410
415
440
Password
Password
420
455
Access Code
425
Card Data Storage
Public Key
Private Key
430
Private Key
Public Key
435
460
Smartcard I.C.

Fig. 3

ENCRYPTED DATA STORAGE CARD INCLUDING SMARTCARD INTEGRATED CIRCUIT FOR STORING AN ACCESS PASSWORD AND ENCRYPTION KEYS

This application is a continuation of application Ser. No. 08/161,854 filed Dec. 6, 1993, abandoned.

FIELD OF THE INVENTION

This invention relates generally to methods and apparatus for storing, processing and communicating private data.

BACKGROUND OF THE INVENTION

Computers are widely used to store and process information which is considered private. For most businesses, the confidentiality of computer data is maintained using the practice followed for conventional business data: restricting access to office space where sensitive records are kept, whether those records take the form of documents kept in file cabinets or machine-readable data stored in an computer.

As the capabilities and usefulness of laptop and notebook computers have increased, functions formerly performed within the security of the office have moved to the field. Sales personnel and executives often travel with computers loaded with confidential data on pricing, customers, and strategic planning. Although available encryption and decryption programs can be used to protect such data when it is not in use, these programs are often inconvenient to use or provide poor security as a result of inadequate key management.

Encryption methods typically rely on "secret keys" known only to authorized users of the protected data. In the widely used Data Encryption Standard ("DES") developed and promulgated by the National Bureau of Standards, data is encyphered in 64-bit blocks using a single 56-bit key, as described in National Bureau of Standards' Federal Information Processing Standards Publication 46, "Data Encryption Standard," National Bureau of Standards (1977). Encryption techniques using two keys, one for encypting the data and a different key for decryption, are called "public key" systems because the encryption key can be made public so that anyone can use the public key to encrypt sensitive data, but only a recipient with the secret key can decrypt it. One widely used and highly effective public key algorithm known as the "RSA" system, named after the inventors Rivest, Shamer and Adelman, is described in Rivest et al. U.S. Pat. No. 4,405,829.

The security of both single-key and public-key encryption systems depends on user's ability to keep the key or keys secret. Although both the DES and RSA encryption algorithms themselves can be depended upon to provide adequate security, neither system can safeguard data if the keys can be learned. The management of the keys themselves accordingly presents the most difficult component of good data security system.

SUMMARY OF THE INVENTION

It is an object of the invention to securely store private information in a compact, easily transportable storage device which may be detached from the computer with which it is used.

It is still another object of the invention to protect such electronically stored data against unauthorized access when the detachable storage device is lost or stolen.

It is a further object of the present invention to provide a secure data storage device which may, at the option of the user, selectively limit access to all or part of the stored data using one or more passwords.

It is a related object of the invention to securely store access passwords, encryption or decryption keys, or digital signatures, in a tamper-proof substorage unit interconnected with a data access mechanism which are integral parts of a detachable computer memory card.

In a principle aspect, the present invention takes the form of a removable memory card, preferably implemented in conformity with the PCMCIA (Personal Memory Card Industry Association) interface standard, which provides the host computer to which it is connected with additional high-speed storage, the memory card consisting of a data storage unit, storage-access locking circuitry, and a tamper-proof key information substorage unit. In accordance with the invention, the locking circuitry is adapted to prevent access to the data stored on the memory card unless the would-be user first presents identifying information which is validated by the locking circuitry with reference to one or more key values stored in the key information substorage unit.

The removable memory card contemplated by the present invention allows data stored on the card to be made immediately available to the connected host computer upon proper presentation of a password known only to an authorized user. Once the password has been validated, the stored data may then be made available to the host processor in decrypted form.

In accordance with the invention, the key information substorage unit advantageously takes the form of a "smartcard" integrated circuit capable of storing secret key values which may be used to provide password-protected access to the data stored on the memory card, or optionally to provide secure storage for the encryption or decryption keys, or digital signatures, needed to allow the host computer to access and/or operate a secure information storage or telecommunications system. In accordance with the invention, access to data, passwords, digital signatures, or other key values stored on the memory card is limited to those who (1) have physical possession of the memory card and (2) knowledge of the memory card access password stored in the card's secure substorage unit.

The smartcard integrated circuit advantageously stores such passwords, public key and secret key values, and/or digital signatures in an Electrically Erasable Programmable Read Only Memory (EEPROM), and further includes its own microprocessor containing a stored program to allow reading and writing of the EEPROM through a serial I/O interface. The stored program within the smartcard IC allows an access password to be programmed into the EEPROM from an external source via the serial interface, but thereafter prevents that password value from being accessed. For enhanced security, the smartcard integrated circuit includes means for monitoring voltages and frequencies to detect abnormal conditions which may indicate an attempt to tamper with the key storage unit to gain unauthorized access to the stored secret key information.

These and other objects, features and advantages of the present invention will become more apparent by considering the following detailed description of a preferred embodiment of the invention, during which frequent reference will be made to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 of the drawings is a block diagram of a secure memory card which embodies the principles of the inven-

tion, the memory card being shown interconnected with a host computer which is in turn connected to other computers by telecommunications links.

FIG. **2** is a data flow diagram depicting a preferred mechanism for providing password protection for information stored within a memory card of type shown in FIG. **1**.

FIG. **3** is a data flow diagram illustrating the use of a secure data card as show in FIG. **1** to protect the privacy of information being sent between a host computer and a remote computer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

HARDWARE

As illustrated in FIG. **1** of the drawings, the preferred embodiment of the invention takes the form of a personal computer memory card indicated generally at **100**. The memory card **100** is interconnected with a host computer **110** by means of a hardware and software interface which conforms to the Personal Computer Memory Card International Association (PCMCIA) standard which has been widely accepted for use in laptop and notebook computers. PCMCIA cards are commonly used to provide additional high-speed memory capacity to the connected host computer, or to implement fax and data modems, network access devices, and hard-disk mass storage devices. Type 1 PCMCIA cards have a form factor typically used to provide additional memory for data and application programs, while the thicker Type 2 cards are used to add telecommunications features and Type 3 cards are used for high-capacity hard disk drives that store up to 100 megabytes of data.

The removable character of PCMCIA storage devices can provide better data security than storage built into the computer itself, because the card may be detached from the computer and placed in a secure area when not in use. However, the cards themselves remain subject to possible theft or misuse. The embodiment of the invention shown in FIG. 1 provides significant additional security for data and programs stored in a detachable memory card by incorporating an access-locking mechanism for preventing access to the stored data by those who are unable to present an authorizing password.

The secure memory card **100** contemplated the invention is adapted to be connected via its PCMCIA interface to the host computer **110** which may in turn be connected to other computers by modem, or by a network, as illustrated by the connection of remote computer **120** via the telecommunications link **130** seen in FIG. 1.

The secure memory card **100** stores data in a common memory array **150**, preferably implemented with non-volatile flash memory integrated circuits, enabling the common memory array to store 10 megabytes of data in an area small enough to be included on a credit-card sized Type I PCMCIA card. The data is stored in random access locations specified by address values supplied via the PCMCIA's standard 26-bit address bus terminals **161**. The address terminals **161** provide address signals to an input address bus buffer circuit **163** which drives an internal address bus **165**. Data transfers between the common memory array **150** and the host computer **110** are accomplished via the interface data terminals **171**, a data bus buffer **173**, an internal data bus **175**, a internal encryption/decryption unit **177**, a gate **178** and an internal data bus **179**. Control signals are exchanged between the common memory array **150** and the host computer via the PCMCIA interface control terminals **181** and an internal control bus **185**.

The address terminals **161**, data terminals **171** and control terminals **181** seen in FIG. **1** are a simplified representation of the **68** pin PCMCIA standard interface which includes provision for 26 parallel address conductors (A0–A25), 16 parallel data conductors (D0–D15) and a remaining set of power and control conductors including power and ground connections and a collection of memory control signal connections (enable, select, wait, write, detect, etc.). The PCMCIA standard achieves interchangeability of cards of different functions by establishing standards for the physical card (dimensions and mechanical tolerances for the card and connectors), the card interface (pinout and signal definitions), and card software (which specifies the organization of data on the card and the record formats and protocols by which configuration information and data is exchanged with the host computer). Complete information which defines the PCMCIA standard is published by and available from the Personal Computer Memory Card International Association, 1030G East Duane Avenue, Sunnyvale, Calif. 94086. The present embodiment of invention conforms to the PC Card Standard Specification, Release 2.01, published in November, 1992.

To implement the PCMCIA interface standard, the secure memory card includes a non-volatile attribute memory **190** which stores information enabling the host computer to automatically identify the particular PCMCIA card as soon as the card and host are connected, and to automatically establish the appropriate hardware/software interface using suitable driver software which executes on the host computer **110**.

The attribute memory **190** shares the internal address bus **165**, data bus **175** and control bus **185** with the common memory array **150**. An address decoder **195** monitors the address bus **165** and provides selection signals to the attribute memory **190** via a attribute memory enable line **197** when addresses within the address space of attribute memory **190** appear on address bus **165** concurrently with the activation of the Attribute Memory Select signal terminal -REG (not separately shown in FIG. **1**) in the PCMCIA connector interface.

Similarly, the address decoder **195** selects the common memory array **150** whenever the address on address bus **165** is within the address space of array **150** by energizing an common memory enable line **210** which supplies an enable signal to the gate **178** in the data pathway to the common memory array **150**.

Gate **178** prevents the common memory array **150** from exchanging data with the host **150** via data bus **179** unless an authorization signal is supplied to the gate **178** via a control line **219** from a card lock logic circuit **220**. The card lock logic circuit **220** is connected to address decoder **195** via the lock enable line **221**, permitting card logic **220** to identify addresses which designate memory locations in the common memory array **150** to which access may be denied under appropriate circumstances. The card lock logic circuit **220** is connected to the internal data bus **175** which provides a pathway for downloading memory access control commands from the host computer **110**.

A smartcard input/output enable line **198** transmits an enable signal from the address decoder **195** to a Universal Asynchronous Receiver Transmitter (UART) **230** when information is to be transferred between the host computer **110** and a smartcard integrated circuit **250**. The UART **230** is connected to the internal data bus **175** and operates to translate data received in bit-parallel form from databus **175** into bit serial form for transfer to the smartcard integrated circuit "I.C." via its serial port **255**.

The smartcard I.C. includes its own processor **260** and non-volatile EEPROM memory circuits **257** which operate as a secret key information substorage system. The processor **260** within the smartcard I.C. **250** is programmed to store secret key codes within the EEPROM **257**, but to thereafter prohibit the stored secret keys from being accessed by any external interrogation. The smartcard I.C. may be implemented with a number of available devices, including the ST16F48 CMSO MCU-based Safeguarded Smartcard IC, with 8k EEPROM, available for SGS-Thomson Microelectronics, a member of the SGS-Thomson ST16XYZ family of devices, as specified in the SGS-Thomson Data Book (April, 1993). The ST16F48 includes an 8-bit processor, 288 bytes of RAM scratchpad storage, an 8k byte EEPROM data memory which forms the secure substorage unit, and a 16k byte program storage read-only memory for storing processing routines, including routines for processing and validating key values supplied to and read from the smartcard I.C. via the UART **230**.

Data transfers and operations, both within the memory card **100** and between the card **100** and the host computer **110**, are controlled by the card lock logic circuit **220**. When the lock circuit enable line **221** is activated in response to the detection of an access control command address value by address decoder **195**, the card lock logic circuit **220** responds to commands and data supplied to the internal data bus **175** from the host computer **110** via the data conductors **171** and the data bus buffers **173**. The card lock logic circuit **220**, the UART **230** and the smartcard I.C. **260** operate under the control of a common timing signal provided by an on-card clock generator circuit seen at **290** in FIG. **1**.

The address space provided by the common memory array **150** is preferably partitioned into independently accessed regions. Each partition is specified in a Card Information Structure or "CIS" (to be described) which is stored in the attribute memory **190**, and preferably corresponds to the memory space provided by one or more integrated circuits making up the array **150** such that a particular partition may be selected by the address decoder **195** which activates particular chip enable lines with the common memory enable output **210**.

The access password itself is stored in the EEPROM **257** within the smartcard I.C. **250**, the password storage operation being accomplished within the memory card **100** whenever a card lock logic activation address is supplied via address terminals **161** and the address buffer **163** to the address decoder **195** which in turn activates the card logic enable line **221**. A password loading command applied via the data interface terminals **171** from the host computer is recognized by card lock logic **220** which channels the subsequent data sequence (the password itself) via the UART **230** and the serial port **255** of the smartcard I.C. **250** for storage at a predetermined location in the EEPROM **257**.

Once a password has been stored for a particular partition, the card lock logic circuit **220** has exclusive control over access to that partition. Any attempt to access that partition (as detected by the address decoder **195**) will be rejected, notifying the device driver software that a valid password must be provided. The driver software then prompts the user with a request for a valid password which, when entered, is sent via the data buffer **173** for validation. The card lock logic **220** routes the offered password to the smartcard I.C. with a request that it be compared with the password stored in the EEPROM **257**. If the passwords match, the smartcard I.C. so notifies the card lock logic **220** which in turn notifies the device driver software executing in the host that the partition has been successfully unlocked. Thereafter, when addresses within the unlocked partition are detected by the address decoder **195**, the card lock logic will activate the gate **178** to permit data transfers between that partition and the data terminals **171**.

To provide additional security, the data transferred over the 16-bit data bus between the data bus buffer **173** and the gate **178** is processed by the encryption-decryption unit **177** which preferrably emplements a symmetrical key algorithm, such as DES, based on a key value which stored in and fetched from the EEPROM **275** in the smartcard I.C. **250**. The unit **250** encrypts data from the data bus buffer **173** prior to storing the data in the common memory array **150**, and decrypts the data back into its original form when it is retrieved from the common memory array **150**. This additional encryption mechanism protects data stored in the common memory array even if that data is successfully read from the flash memory chips making up the array **150**. As discussed in more detail later, the secure key storage mechanism provided by the memory card may also be used to protect sensitive data being manipulated by mechanisms external to the memory card **100**.

All of the operative circuitry making up the memory card **100**, with the exception of the attribute memory **190**, the common memory array **150**, and the smartcard I.C. **250**, is preferrably implemented by means of a single, monolithic application specific integrated circuit (ASIC) as indicated within the dashed line rectangle **290** in FIG. **1**. By integrating this circuitry in a monolithic integrated circuit, security against invasive attempts to ascertain built-in unlock codes (to be discussed) or to bypass or disable security functions, is substantially improved.

SOFTWARE

As previously noted, the attribute memory **190** stores information which specifies the nature of the memory card **100** and the format used for the information stored on the card. The attribute memory **190** holds a Card Information Structure ("CIS") which is organized in a "Metaformat" defined in Section **5** of the PCMCIA PC (Personal Computer) Card Standard, Release **2.01**, for handling numerous different data recording formats. The CIS is organized as hierarchy of layers and takes the form of a chain (linked-list) of data blocks called "tuples" which begin at address **0** of the attribute memory **190**.

The PCMCIA standard also establishes standards for the operation of host processor operating system software which can be used to simplify the design of specific device drivers which provide access to the memory card. The standard "Socket Services" and "Card Services" card interface software, when implemented on a given host computer, provides a Card Services interface with "Client Device Drivers," significantly simplifying the design of device drivers by providing much of the functionality required for communicaton with socketed PCMCIA cards. For host computers which are not provided with standard PCMCIA Card Services and Socket Services functions, the device driver directly interrogates the CIS structures in the attribute memory using standard link-list processing techniques, and provide direct software support for the bulk memory functions which would otherwise be supported by the PCMCIA Card Services interface.

Whether utilizing available Card Services routines or directly addressing and manipulating the memory card hardware interface, the device drive itself may be specified in the DOS CONFIG.SYS file and loaded when the host processor is initialized, or may take the form of an independently loadable TSR program. The discussion which follows describes the operation of a Client Device Driver adapted to

operate in conjunction with PCMCIA standard Card Service functions and notification mechanisms.

The programming interface to the PCMCIA Card Services software is defined in Section 3 of the PCMCIA Standard (Release 2.01) which specifies a variety of services which are available to Client Device Drivers, as well as callback mechanisms for notifying Client Device Drivers of status changes. In addition to conventional memory operations provided by Bulk Memory Service functions, the Card Services software also provides Client Utility functions which allow client device drivers to access and manipulate the CIS stored in the memory card's attribute memory **190**. Card management routines, either forming a part of the Client Device Driver or part of a special purpose application program for configuring the memory card according to the users needs, are executed on the host computer. These card management routines in turn utilize the functions provided by the PCMCIA Card Services software to implement the following two special operations which not required for conventional PCMCIA memory cards:

PARTITION LOCK.

This operation accepts two parameters from the user: (1) a password value, typically taking the form of ASCIIZ (null-terminated string) of keyboarded characters entered by a user in response to a prompt, and (2) a partition identifier which specifies a portion of the address space provided by the common memory array **150**. At the same time, the fact that a given partition has been locked, together with an identification of the EEPROM memory location of the password (but not its value) are recorded in the CIS entry for that partition.

The memory card **100** is intitialized as a standard memory card before being first delivered to the end user, and provides one or more freely accessible storage partitions prior to receiving the first PARTITION LOCK command.

PARTITION UNLOCK.

The storage of a password associated with a particular password has the effect of locking that password against subsequent attempts to use the data or programs stored within that partition without first supplying a valid password.

Whenever a PCMCIA card is newly inserted into the socket of a running host computer, the Client Device Driver is notified by the Card Services software (via its CARD_INSERTION callback function), so that it can process the card's CIS entries to identify each partition that may be password-protected. Similarly, when the host computer is first powered up and the Client Device Driver is initialized, the Client Device Driver calls Card Services functions to process the cards CIS entries to identify each partition that may be locked.

The device driver software then attempts to access each identified partition. If the partition is locked (as determined by the mechanism discussed above), the card lock logic **220** notifies the device driver of the locked condition, allowing the device driver to request a valid password from the user, either at the time the host computer is being initialized with an already socketed memory card, or at the time a memory card is first inserted into an already running host computer.

Other Operations.

To support encryption and decryption systems, systems employing digital signatures, and secure telecommunications access protocols, examples of which will be discussed below, the card lock logic unit **220** and UART **230** also provide the capability for storing additional passwords, key values, access codes and the like in the secure substorage system provided by the smartcard I.C. **250**, or alternatively (but less securely) in the common memory array **150** or in the attribute memory **190**.

PASSWORD AND KEY MANAGEMENT

A preferred mechanism for validating the user's password needed to unlock a particular memory partition is illustrated in FIG. **2** of the drawings. First, as previously described, the user who desires to protect information stored on the card supplies a secret password which is written into the smartcard I.C. memory as indicated at **301**. When an attempt is made to access data protected by the secret password **301**, the ASIC **290** implementing the card lock logic unit **220** generates a random number **303** which is supplied to the host computer **110** as indicated at **307**. The host computer **110** then prompts the user to enter a password at **309**. The offered password **309** is combined with the random number **303** at **311** and the result is returned at **313** to the ASIC **290**. The returned value is then combined at **317** with a fixed unlock code **319** (built into the ASIC **290**) to produce a final value which is applied to a first input **321** of a comparator **320**.

At the same time, the random number **303** which was sent to the host is also sent to the smartcard I.C. **250** whose processor **260** is programmed to combine the random number **303** at **325** with the previously stored secret password **301** to form a result value at **327**. The result value **327** is combined at **328** with a copy **330** of the unlock code **319**, and the resulting final value is applied to the second input **322** of the comparator **320**. If the final value at input **321** which is created by the password offered by the user matches the final value at input **322** created by the password stored within the smartcard I.C. **250**, the partition associated with the stored password will be unlocked by sending an activation signal **335** to a data flow gate **340** connected in the path of a data bus **345** connecting the host computer **350** and the memory card's common memory array **360**.

It is important to observe that the data stored in a protected partition within the memory card **100** is available only to those who possess both the card and the password. Neither possession of the card without knowledge of the password, nor knowledge of the password without physical possession of the card, will be sufficient to obtain access to the data.

The combined requirement that the bearer of the card also know the password can be used to provide security for data stored or transmitted outside the memory card, as well as for data stored within the card, as illustrated by the examples depicted in FIG. **3** of the drawings.

As depicted in FIG. **3**, a secure memory card **400** is connected to a host computer **410** and includes a smartcard integrated circuit **415** which provides a secure substorage system which stores a password **420**, an access code **425**, a private key value **430**, and a public key value **435**.

The password **420** is used to verify the identity of the bearer of the memory card, who is required to enter of a valid password **440** when prompted by the host computer as previously discussed in conjunction with FIG. **2**. Unless a valid password **440** is known to the bearer of the memory card **400**, the additional codes and keys **425**, **430** and **435** cannot be retrieved from the smartcard I.C. Requests for access to the a stored key is passed to the smartcard I.C. and processed by routines stored in the smartcard I.C. internal ROM program store, which denies any incoming request which is not accompanied by the submission of a valid password **440**. However, if the bearer of the memory card **400** can provide a valid password **440** which matches the stored password **420**, the following additional secure transactions are made possible between the host computer **410** and a remote computer **450**.

First, the remote computer **450** may deny access to one or more of its capabilities unless a proper access code is transmitted from a would be remote station which establishes communications with the computer **450**, typical via a dial-up telephone connection using modem transmission, or by a dedicated connection in a network or the like. By storing the needed access code in the a password-protected PCMCIA card, an improved mechanism is provided form establishing the authority of a remote caller to access designated functions in the remote computer. Preferably, the validity of the stored access code is established by a challenge-and-response exchange of the type illustrated in FIG. **2**, in which the remote computer **450** transmits a challenge in the form of a random number which is combined with the stored access code **425** to form a response which is returned to the remote computer **450** for verification. In this way, the access code **425** is not transmitted and interception of either the challenge or response values by an intruder monitoring the exchange will not provide the intruder with the access code.

After the host computer **410** establishes its identity to the satisfaction of the remote computer **450** using the stored access code **425**, the host computer then may request the transmission of encrypted data from the remote computer. To accomplish this, the two stations may use a two key encryption and decryption mechanism in which the remote computer **450** encrypts the data to be transmitted with a public key **455** and the host computer, using the private key value **430** stored in the smartcard I.C. **415**, decrypts the received transmission to obtain the desired message text. Other computers in the network in possession of the public key **455** may also send secure transmissions to the host computer **410**, but cannot decrypt such messages from others since only the possessor of the private key **430** is able to decrypt the transmissions.

Alternatively, the smartcard I.C. may store one or more public key values such as the public key **435** which enables the host processor to send secure transmissions to a selected remote receiving computer in possession of the corresponding private key **460**. In the same way, single key encryption mechanisms such as DES, and systems requiring the identification of remote senders using digital signature techniques can be readily implemented using the password protected secure memory card as the mechanism for storing the needed key values.

The DES and RSA Encryption schemes, as well as numerous other systems for the secure information transmission and retention are described in detail in *Applied Cryptography: Protocols, Algorithms, and Source Code in C* by Bruce Scheier, John Wiley & Sons (1994), ISBN 0471597562. The use of the detachable, password protected secure memory card contemplated by the present invention provides additional security by providing an improved key management mechanisms which requires that a would-be user of such a system have both physical possession of the memory card (which holds the needed key values) and knowledge of the password which permits the key values to be accessed.

It is to be understood that the specific mechanisms and techniques which have been described are merely illustrative of on application of the principles of the invention. Numerous modifications may be made to the methods and apparatus described without departing from the true spirit and scope of the invention.

What is claimed is:

1. A removable memory card including external interface terminals for establishing data, address, control and power pathways between said card and corresponding socket terminals of a host computer, said memory card comprising:

a smartcard integrated circuit including a local processor and a substorage memory unit for storing a first password value and an encryption key value,

a non-volatile data storage memory,

gating means having a control input, said gating means being connected to establish a data pathway between said interface terminals and said data storage memory only when an authorization signal is applied to said control input, and

card lock logic means coupled to said smartcard integrated circuit for receiving a second password value from said host computer via said interface terminals, said card lock logic means including:

means for applying said authorization signal to said control input of said gating means only when said second password value bears a predetermined relation to said first password value stored in said substorage memory of said smartcard integrated circuit,

means for encrypting data transferred to said data storage memory via said gating means by combining data from said interface terminals with said encryption key value from said smartcard integrated circuit,

means for decrypting previously encrypted data transferred from said data storage means in response to said authorization signal by combining said encrypted data with said encryption key value stored in said substorage memory of said smartcard integrated circuit, and

means for preventing the transfer of said encryption key value from said substorage memory of said smartcard integrated circuit when said second password value does not bear said predetermined relation to said first password value.

2. A data processing system comprising, in combination,

a host computer including a interface connector and means for sending and receiving data via said interface connector, and

a removable memory card including:

interface terminals arranged to establish electrical connections to said interface connector of said host computer,

a data storage memory,

a smartcard integrated circuit including means for storing a first password value and a stored encryption key value,

an encryption and decryption unit connected between said interface terminals and said data storage memory for encrypting data being stored in said storage means by combining data received from said host computer with said encryption key value to produced stored encrypted data, and for thereafter decrypting said stored encrypted data by combining said encrypted data with said stored encryption key value,

gating means for controlling the transmission of data signals between said interface terminals and said data storage memory in response to an authorization signal, and

a card lock logic circuit comprising:

means for receiving a second password value from said host computer via said interface terminals,

detection means coupled to said smartcard integrated circuit and to said gating circuit for generating said authorization signal only if said second password value has a predetermined relationship with said first password value stored in said smartcard integrated circuit, and

means responsive to said authorization signal for transferring said stored encryption key value from said smartcard integrated circuit to said encryption and decryption unit.

3. A removable personal computer memory card for use with a connected personal computer, said card comprising, in combination:

a plurality of external data terminals for establishing a data pathway between said card and said personal computer,

plurality of external address terminals for establishing an address pathway between said card and said personal computer,

a non-volatile data memory having a data port and an address port,

circuit means connected to said address terminals for applying address signals received from said personal computer via said address pathway to enable the transfer of information to or from selected locations in said data memory via said data port,

encryption means connected between said external data terminals and said data port for converting data received from said personal computer via said data pathway into encrypted data applied to said data port for storage in said selected locations in said data memory, said encryption means converting data in response to and in accordance with an encryption key value,

decryption means connected between said external data terminals and said data port for converting data transferred from said selected locations in said data memory into unencrypted data and for transferring said unencrypted data to said external data terminals, said decryption means converting data into said unencrypted data in response to and in accordance with said encryption key value,

a smartcard integrated circuit including a local processor and a secure substorage memory unit for storing a predetermined authorization value and said encryption key value,

first control means for accepting a password value from said personal computer and transferring said password value to said smartcard integrated circuit, and

means including a program executable by said local processor in said smartcard integrated circuit for comparing said password value with said authorization value and for transferring said encryption key value to said decryption means to enable said decryption means only when said password value and said authorization value have a predetermined relationship to one another.

* * * * *

US005485439A

United States Patent [19]

Hamasaka et al.

[11] Patent Number: 5,485,439

[45] Date of Patent: Jan. 16, 1996

[54] **METHOD FOR RECORDING/REPRODUCING INFORMATION AND APPARATUS THEREFOR**

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[73] Assignee: **Matsushita Electric Industrial Co., Ltd.**, Osaka, Japan

[21] Appl. No.: **785,296**

[22] Filed: **Oct. 30, 1991**

[30] **Foreign Application Priority Data**

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Nov. 30, 1990	[JP]	Japan	2-337927
Jul. 4, 1991	[JP]	Japan	3-164320

[51] **Int. Cl.**[6] **G11B 7/00**

[52] **U.S. Cl.** **369/47**; 369/54; 369/58; 369/50

[58] **Field of Search** 369/47, 50, 53, 369/54, 58, 48; 395/425, 600; 360/27

[56] **References Cited**

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5,136,569	8/1992	Fennema et al.	369/53 X

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Primary Examiner—W. R. Young
Attorney, Agent, or Firm—Ratner & Prestia

[57] **ABSTRACT**

A method and apparatus for recording/reproducing information on an optical disk using the UNIX operating system. The optical disk has a plurality of partitions. An open table is provided to prevent the removal of the optical disk when the optical disk device is in use. The open table manages the use situation of the plurality of partitions. The optical disk is prohibited from being removed from the optical disk device when one partition is opened earlier than the other partitions. The removal prohibition of the optical disk is released when the final partition is closed.

3 Claims, 13 Drawing Sheets

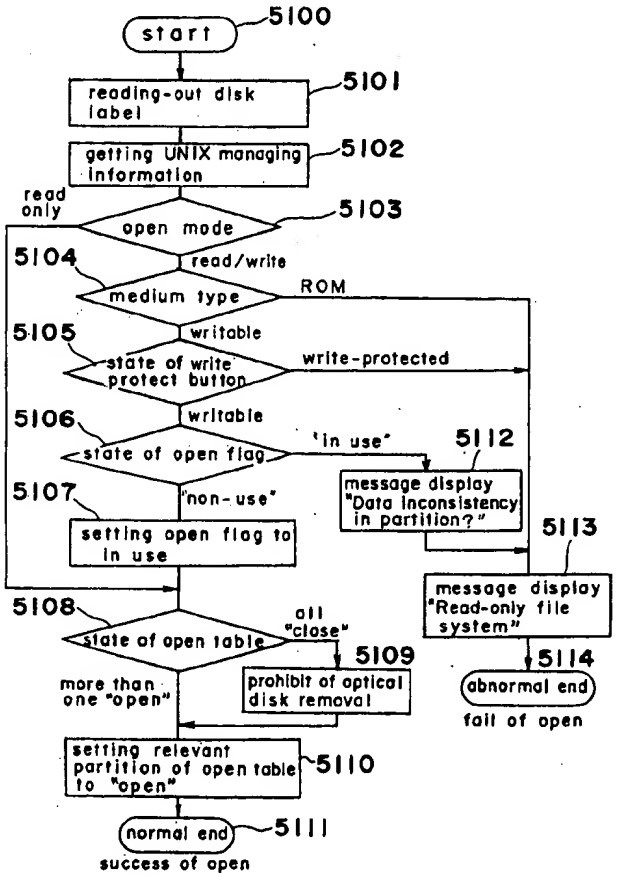


Fig. 1

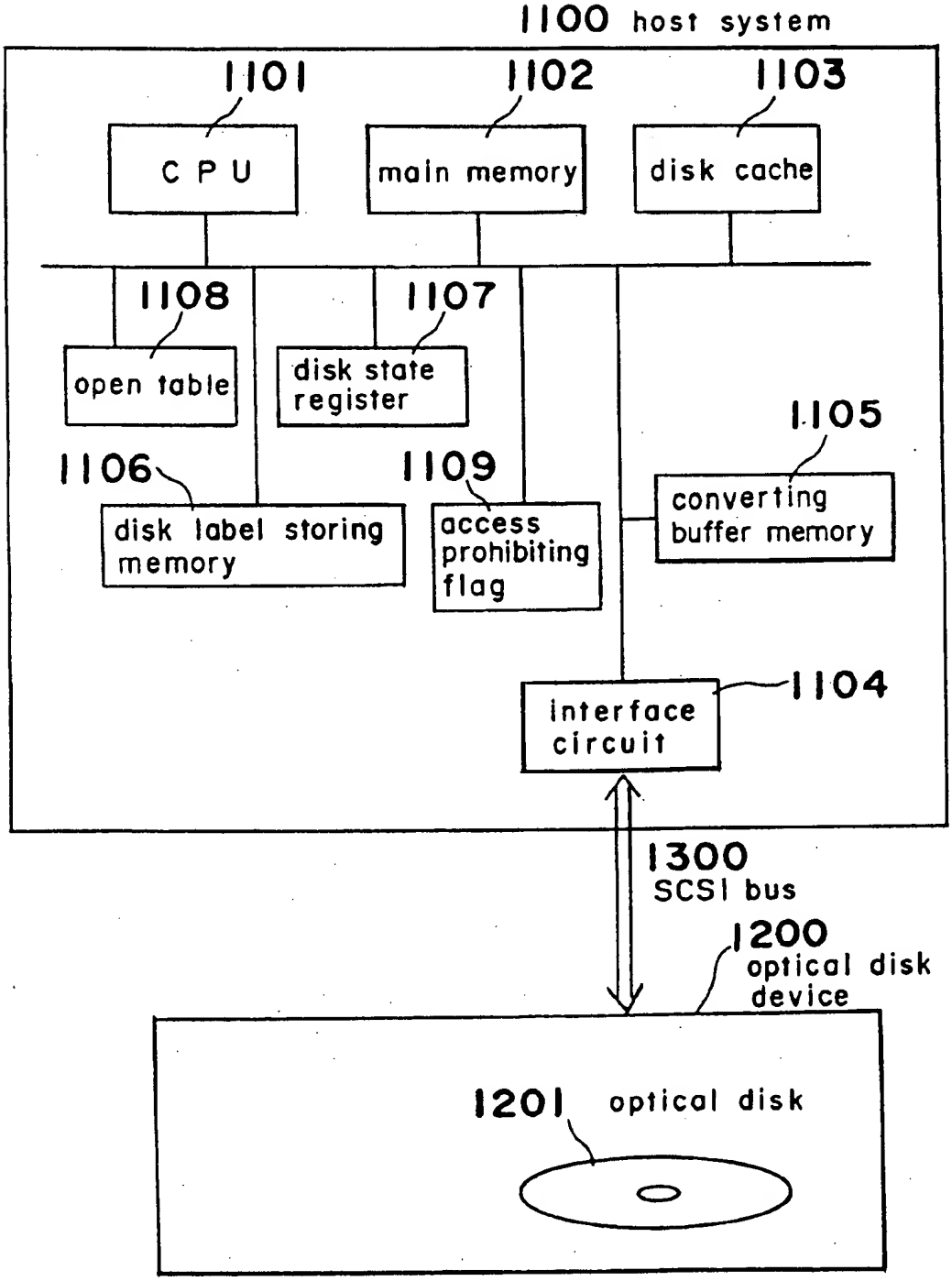

1100 host system
1101
1102
1103
C P U
main memory
disk cache
1108
1107
open table
disk state register
1105
1106
1109
converting buffer memory
disk label storing memory
access prohibiting flag
1104
interface circuit
1300
SCSI bus
1200
optical disk device
1201 optical disk

Fig. 2(A)

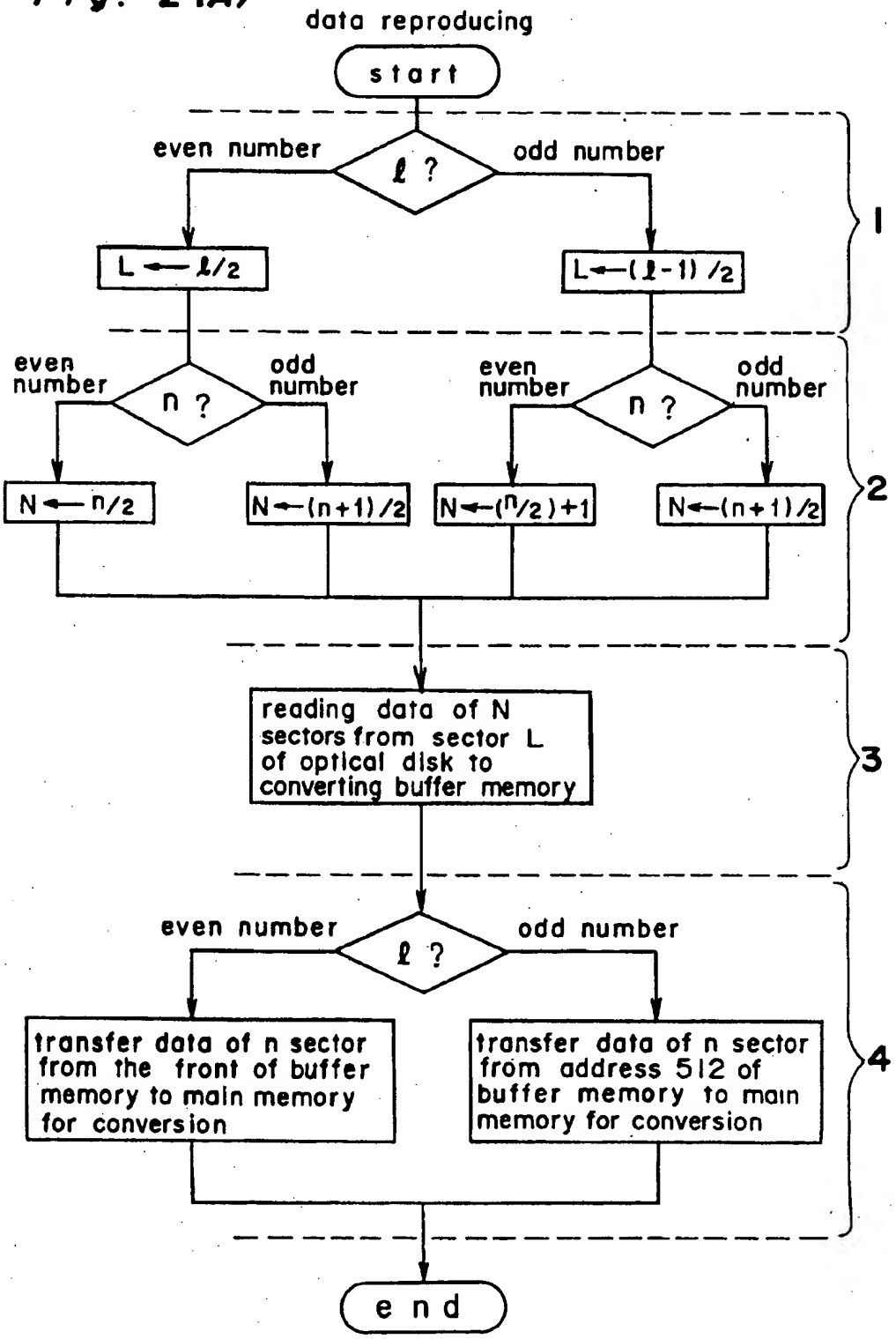

data reproducing
start
even number
ℓ ?
odd number
L ← ℓ/2
L ← (ℓ-1)/2
1
even number
n ?
odd number
even number
n ?
odd number
N ← n/2
N ← (n+1)/2
N ← (n/2)+1
N ← (n+1)/2
2
reading data of N sectors from sector L of optical disk to converting buffer memory
3
even number
ℓ ?
odd number
transfer data of n sector from the front of buffer memory to main memory for conversion
transfer data of n sector from address 512 of buffer memory to main memory for conversion
4
end

Fig. 2(B) data recording

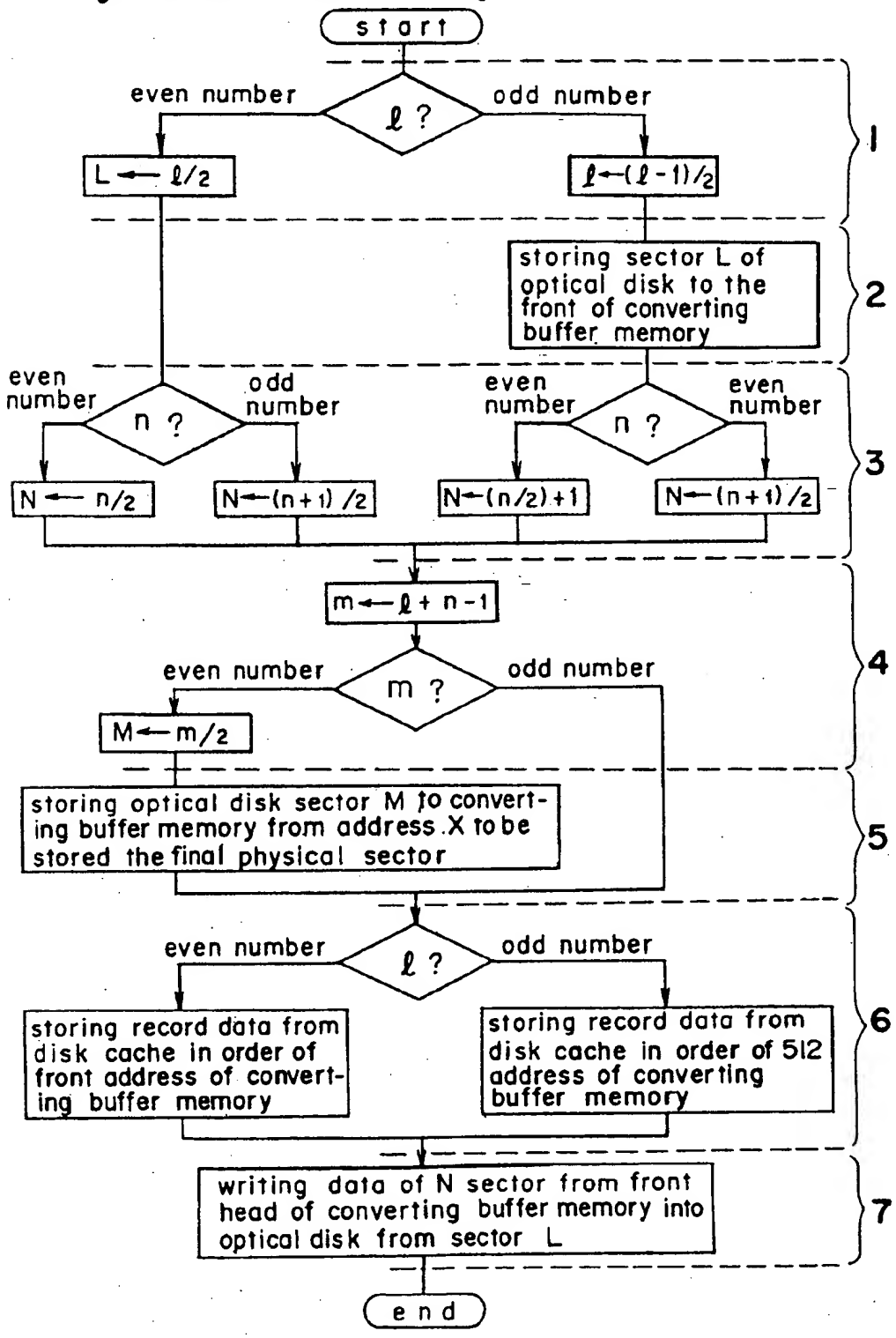


Fig. 3(A)

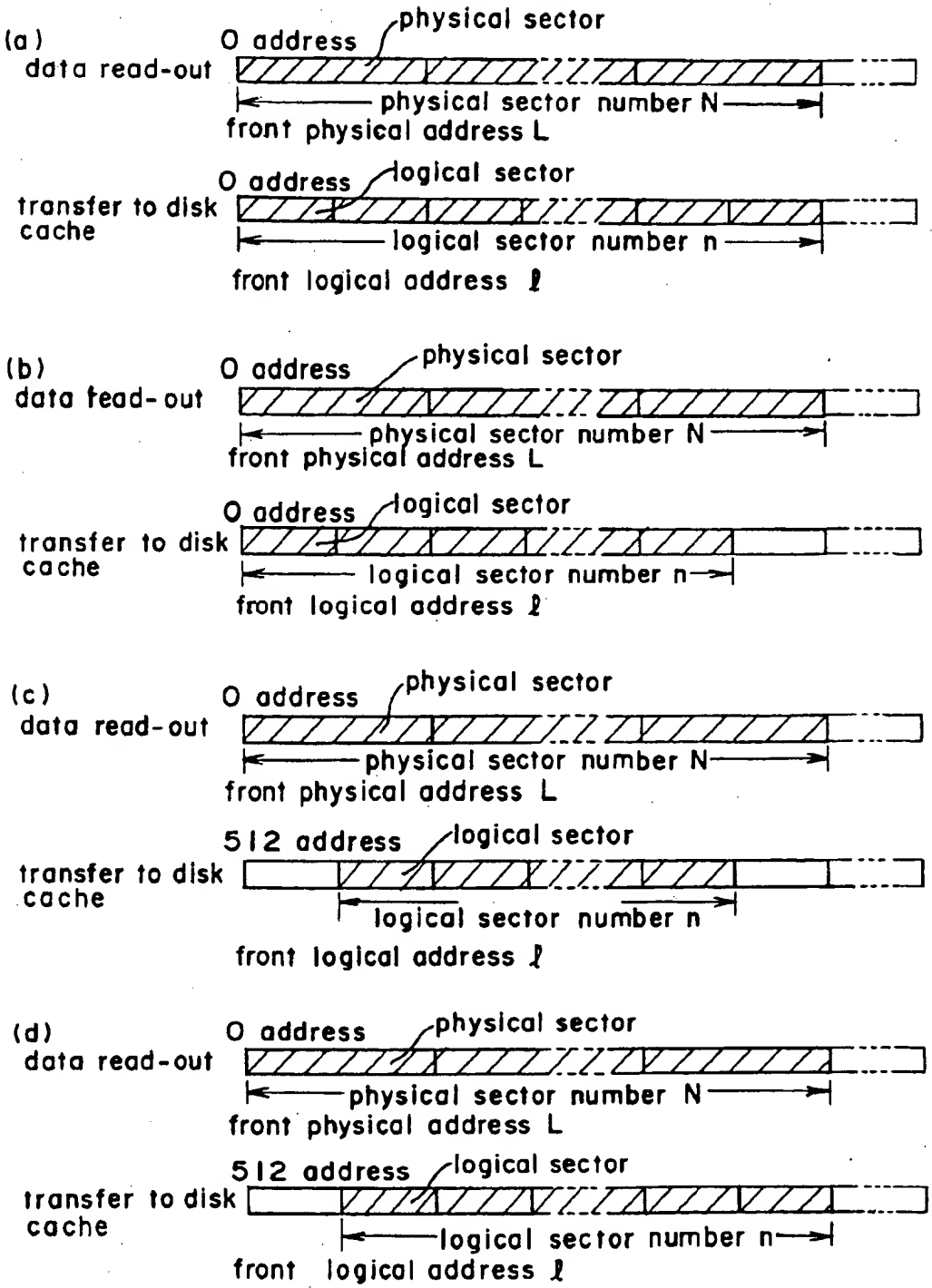

(a)
data read-out
O address
physical sector
physical sector number N
front physical address L
transfer to disk cache
O address
logical sector
logical sector number n
front logical address l
(b)
data read-out
O address
physical sector
physical sector number N
front physical address L
transfer to disk cache
O address
logical sector
logical sector number n
front logical address l
(c)
data read-out
O address
physical sector
physical sector number N
front physical address L
transfer to disk cache
512 address
logical sector
logical sector number n
front logical address l
(d)
data read-out
O address
physical sector
physical sector number N
front physical address L
transfer to disk cache
512 address
logical sector
logical sector number n
front logical address l

Fig. 3(B)

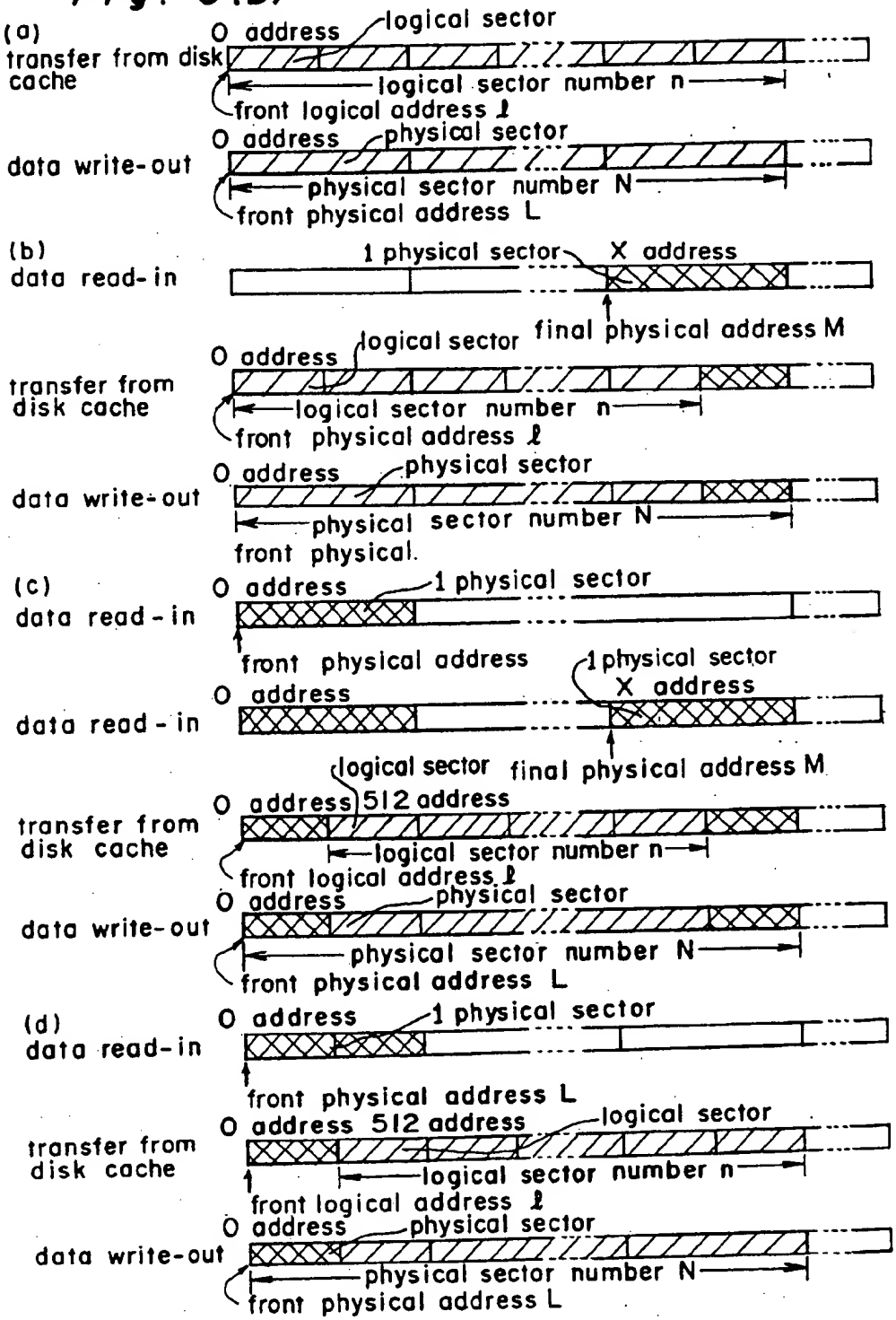
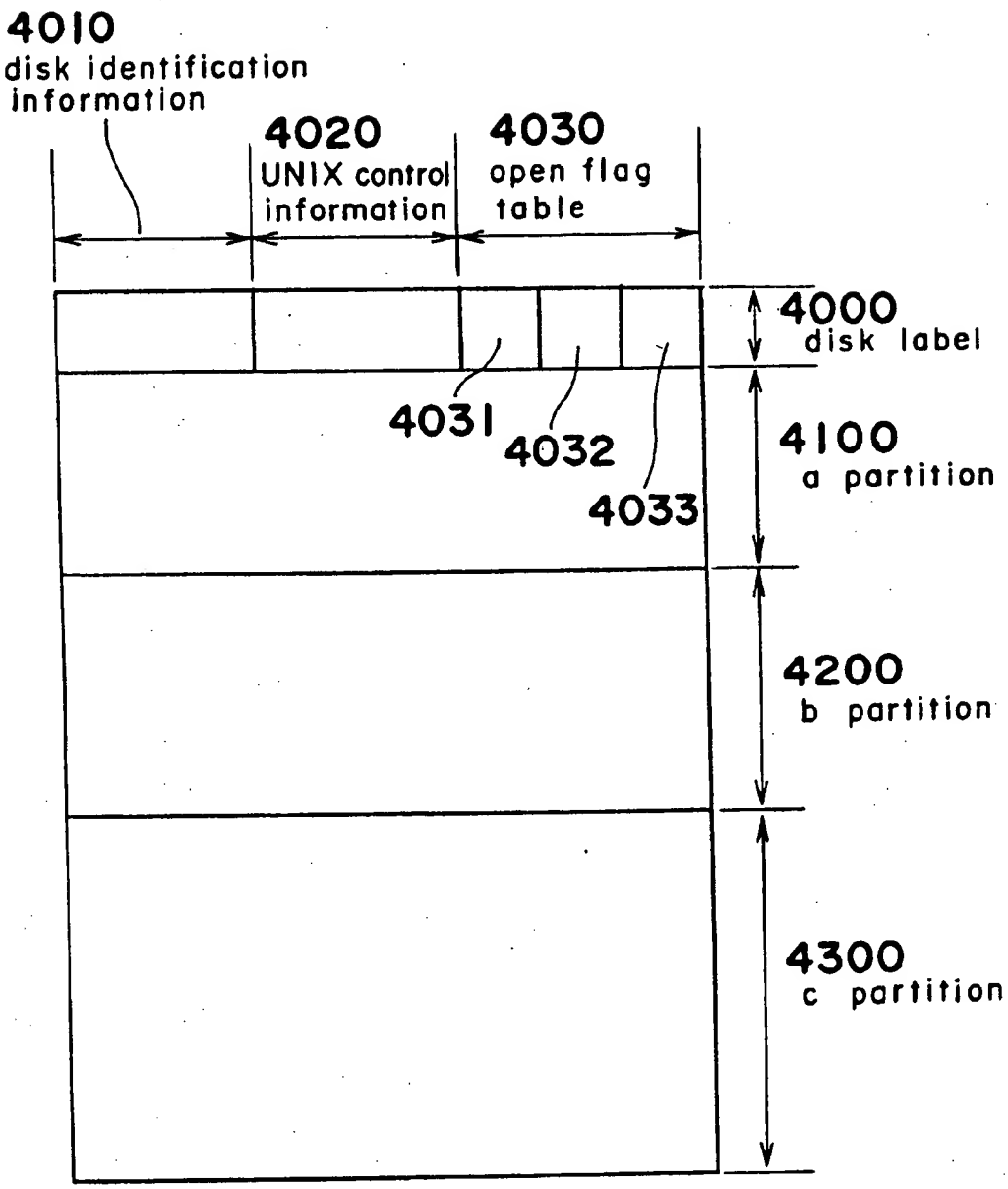

(a)
transfer from disk cache
O address
logical sector
logical sector number n
front logical address ℓ
data write-out
O address
physical sector
physical sector number N
front physical address L
(b)
data read-in
1 physical sector
X address
final physical address M
transfer from disk cache
O address
logical sector
logical sector number n
front physical address ℓ
data write-out
O address
physical sector
physical sector number N
front physical.
(c)
data read-in
O address
1 physical sector
front physical address
data read-in
O address
1 physical sector
X address
final physical address M
transfer from disk cache
O address
logical sector
512 address
logical sector number n
front logical address ℓ
data write-out
O address
physical sector
physical sector number N
front physical address L
(d)
data read-in
O address
1 physical sector
front physical address L
transfer from disk cache
O address
512 address
logical sector
logical sector number n
front logical address ℓ
data write-out
O address
physical sector
physical sector number N
front physical address L

Fig. 4



4031 open flag of a partition

4032 open flag of b partition

4033 open flag of c partition

Fig. 5 (A)

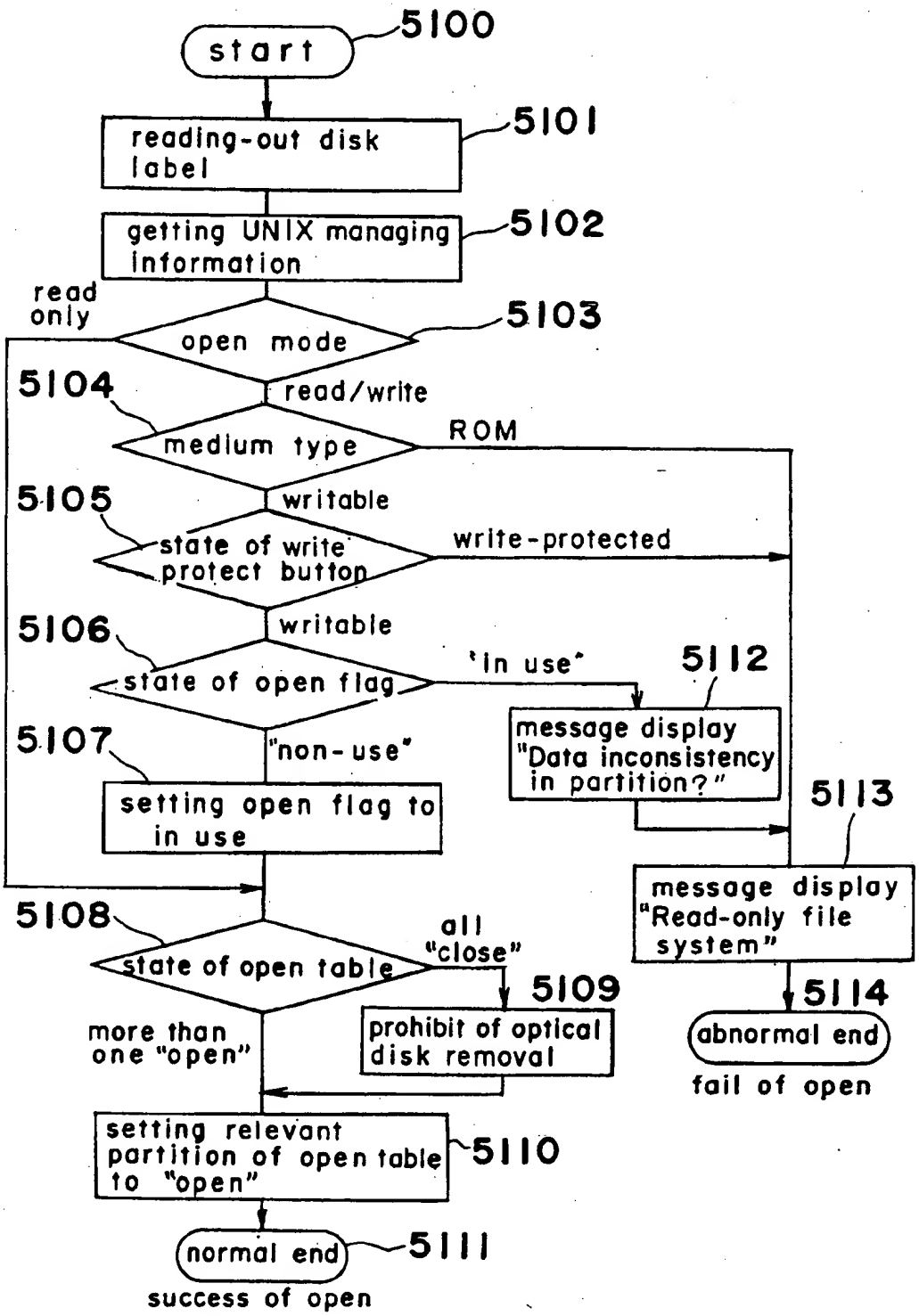

start
5100
reading-out disk label
5101
getting UNIX managing information
5102
read only
open mode
5103
read/write
5104
medium type
ROM
writable
5105
state of write protect button
write-protected
writable
5106
state of open flag
'in use'
5112
message display "Data inconsistency in partition?"
5113
message display "Read-only file system"
5114
abnormal end
fail of open
"non-use"
5107
setting open flag to in use
5108
state of open table
all "close"
5109
prohibit of optical disk removal
more than one "open"
setting relevant partition of open table to "open"
5110
normal end
5111
success of open

Fig. 5(B)

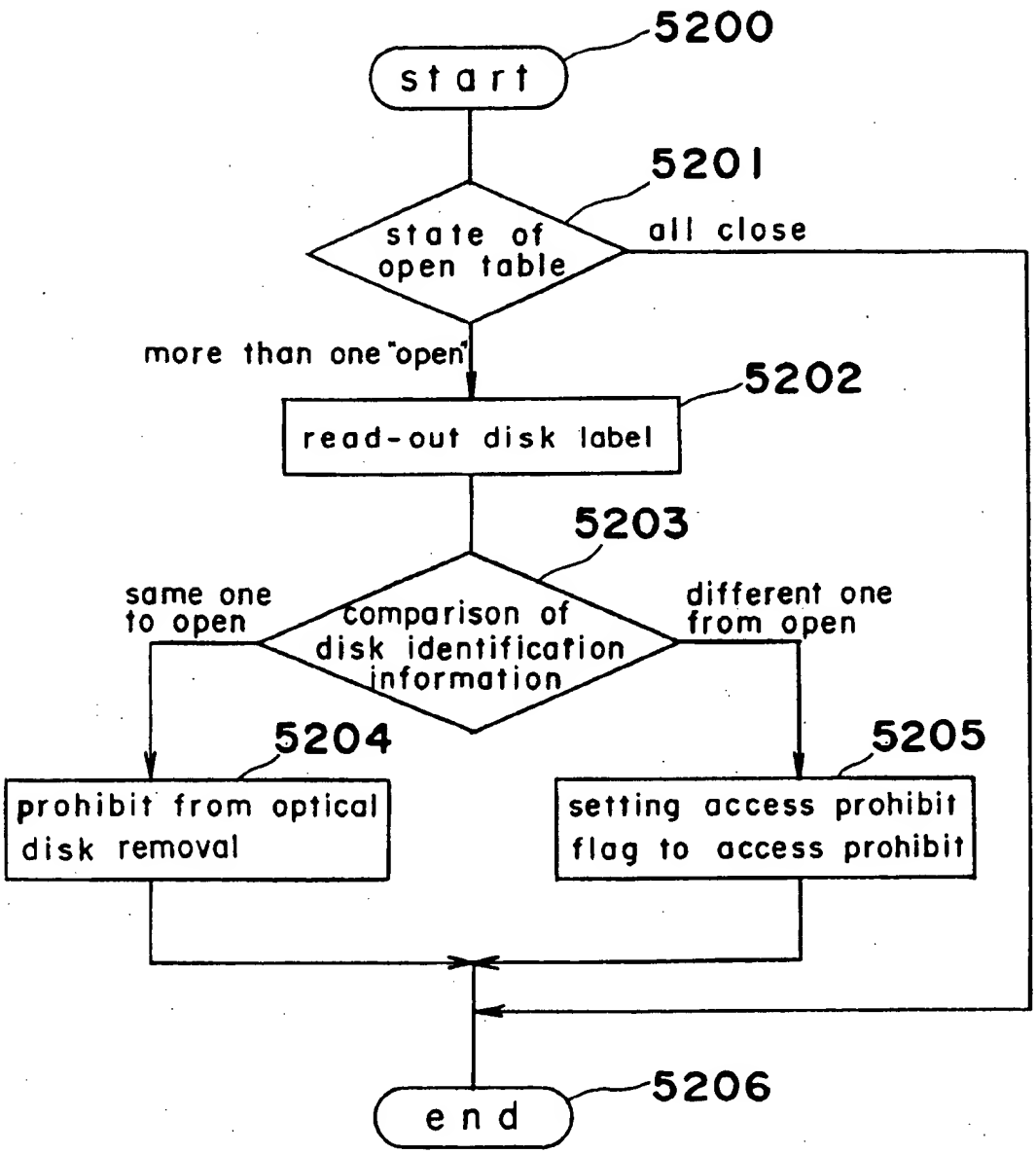

5200
start
5201
state of open table
all close
more than one "open"
5202
read-out disk label
5203
comparison of disk identification information
same one to open
different one from open
5204
prohibit from optical disk removal
5205
setting access prohibit flag to access prohibit
5206
end

Fig. 5(C)

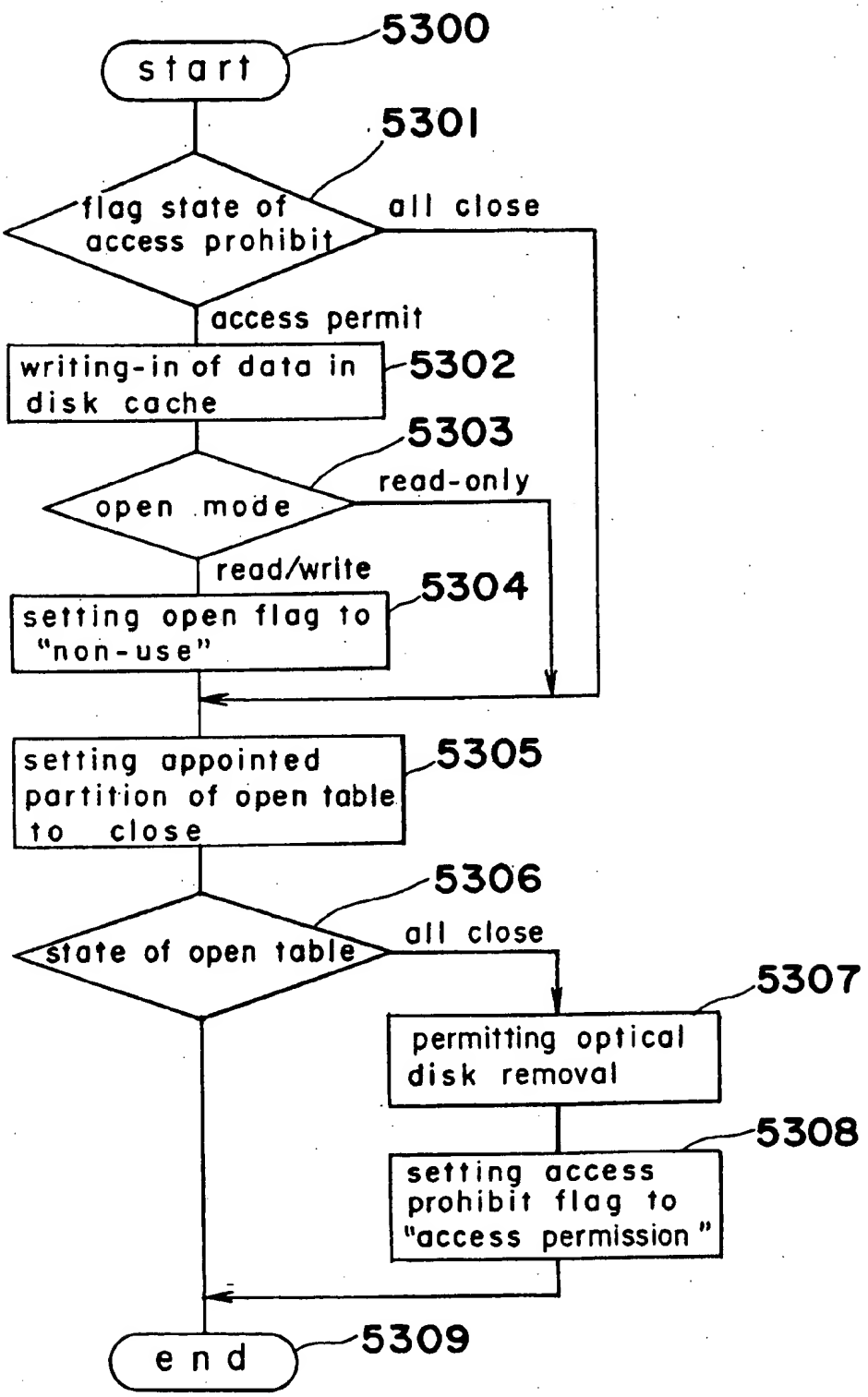

start
5300
5301
flag state of access prohibit
all close
access permit
writing-in of data in disk cache
5302
5303
open mode
read-only
read/write
setting open flag to "non-use"
5304
setting appointed partition of open table to close
5305
5306
state of open table
all close
5307
permitting optical disk removal
5308
setting access prohibit flag to "access permission"
end
5309

Fig. 5(D)

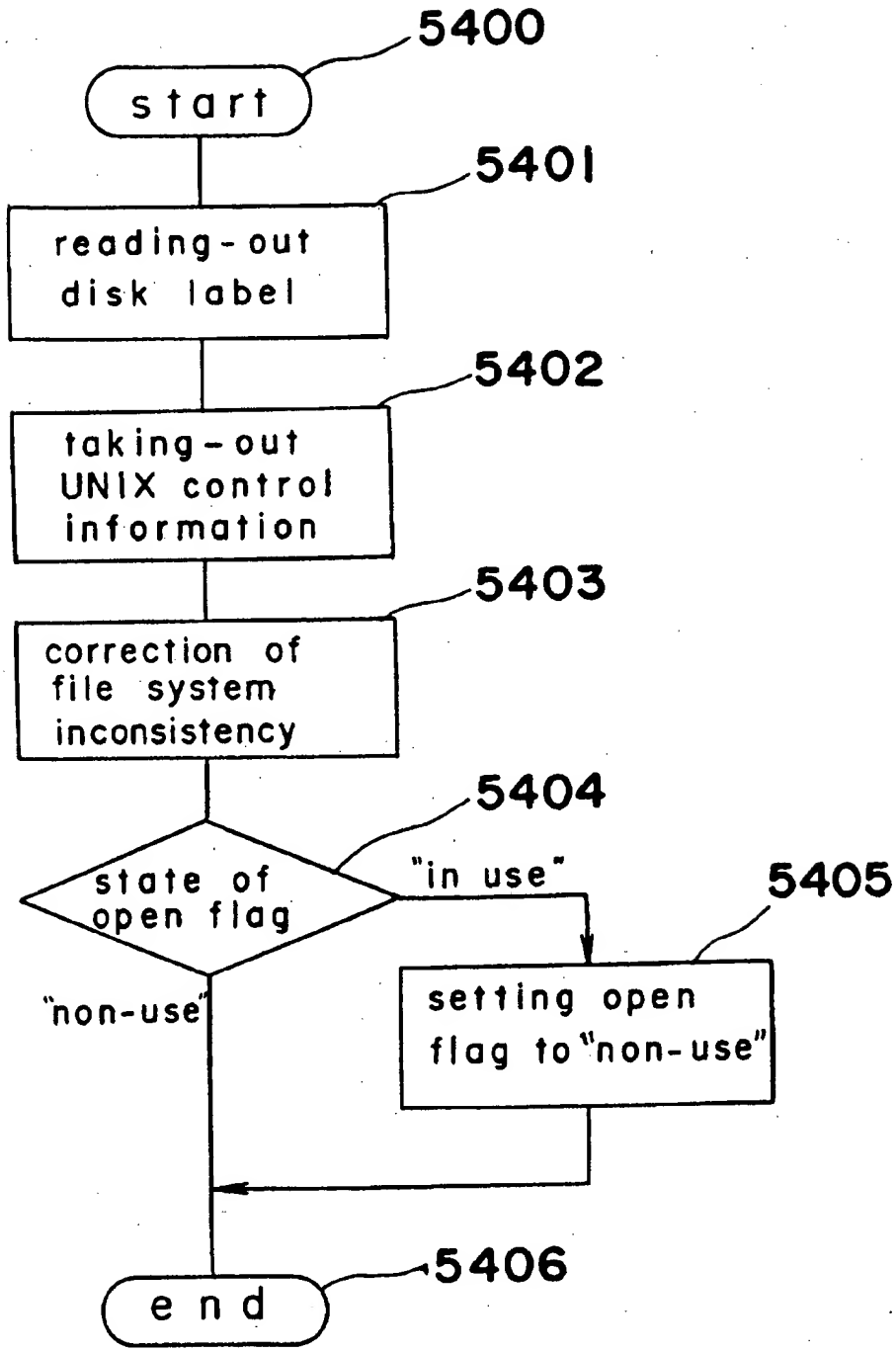

5400
start
5401
reading-out disk label
5402
taking-out UNIX control information
5403
correction of file system inconsistency
5404
state of open flag
"in use"
5405
"non-use"
setting open flag to "non-use"
5406
end

Fig. 6

(a)

a	b	c
close	close	close

(b)

a	b	c
open	close	close

(c)

a	b	c
open	open	close

(d)

a	b	c
close	open	close

(e)

a	b	c
close	close	close

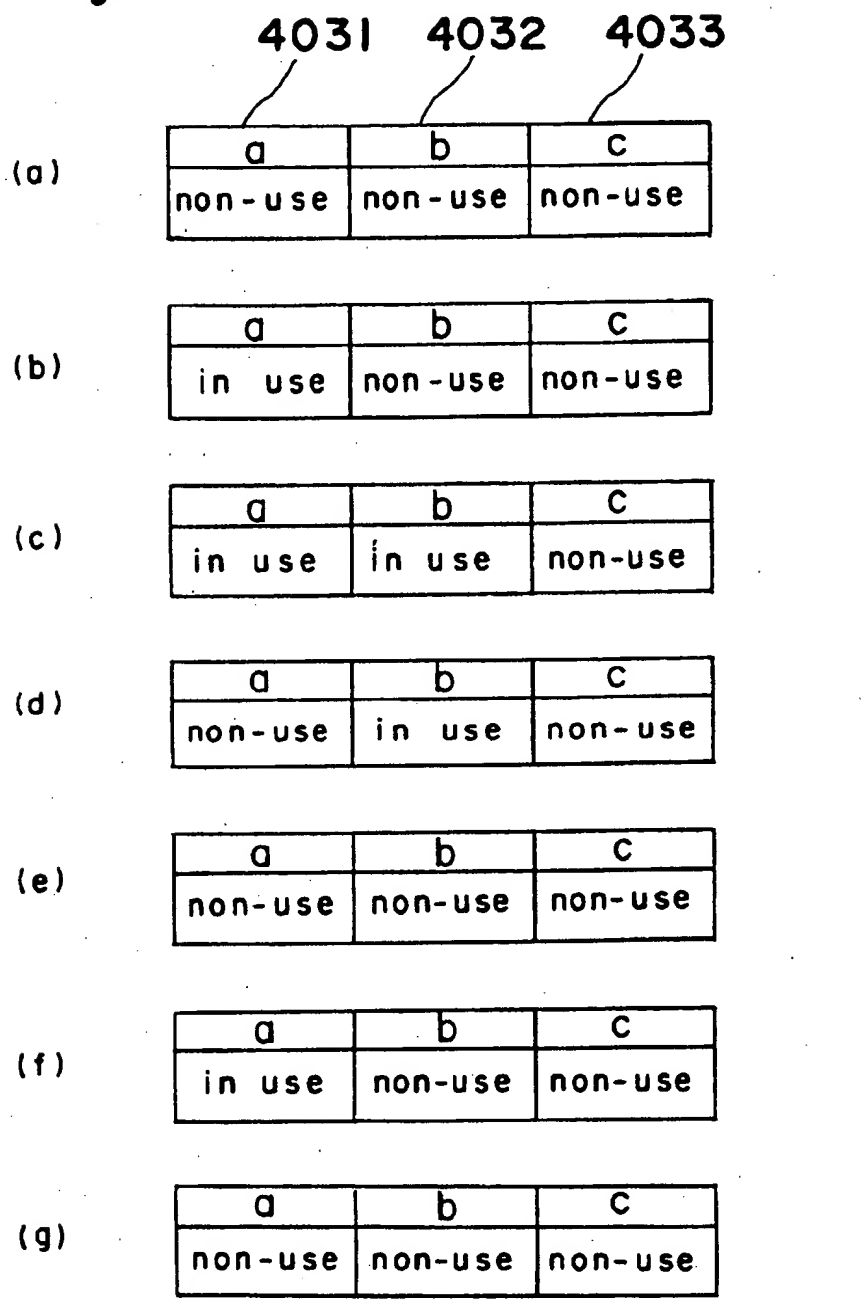
(f)

a	b	c
open	close	close

(g)

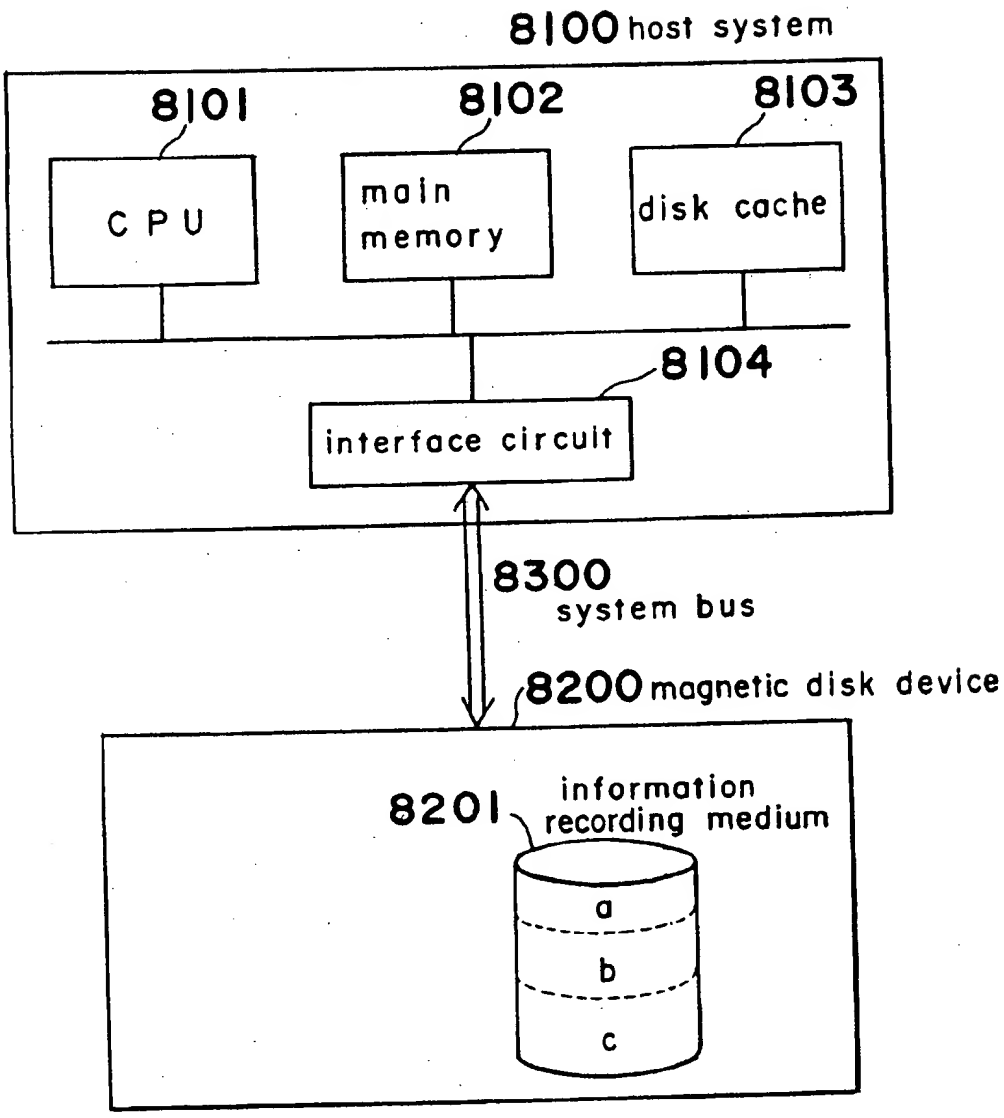
a	b	c
close	close	close

Fig. 7



4031 open flag of a partition
4032 open flag of b partition
4033 open flag of c partition

Fig. 8 PRIOR ART



METHOD FOR RECORDING/REPRODUCING INFORMATION AND APPARATUS THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and an apparatus for recording/reproducing information in which an optical disk is used as an information recording medium.

2. Description of the Prior Art

The operation of a conventional information recording reproducing apparatus is described below.

FIG. **8** is a construction view showing the conventional information recording reproducing apparatus, using UNIX as an operating system, in which a host system **8100** is connected with a magnetic disk device **8200** serving as an external memory via a system bus **8300**.

The host system **8100** comprises a CPU **8101**, a main memory **8102**, a disk cache **8103**, and an interface circuit **8104**. The main memory **8102** stores a plurality of programs and data. The CPU **8101** reads out the data and the programs stored in the main memory **8102** into execution. The disk cache **8103** is a memory for making input/output processings at a high speed. The input and output of data between the host system **8100** and the external memory is carried out via the disk cache **8103**. The interface circuit **8104** connects the host system **8100** to the system bus **8300**.

The magnetic disk device **8200** accommodates an information recording medium **8201**. The information recording medium **8201** is logically divided into three partitions a, b, and c and a file system is constructed in each partition.

The recording reproducing operation of the data in the conventional information recording reproducing of the above construction is described below.

The CPU **8101** reads out the program from the main memory **8102** into an execution. When the writing of data on the partition (a) of the information recording medium **8201** is necessary in this process, the CPU **8101** opens the partition (a) in read/write mode. In the open processing, the CPU **8101** reads out the management information required in controlling the file from the information recording medium **8201** via the interface circuit **8104**.

Next, the CPU **8101** records data in the partition (a) of the information recording medium **8201**. In the write processing of data, first, the CPU **8101** transfers data to be written to the disk cache **8103** from the main memory **8102**.

When the CPU **8101** records the data from the main memory **8102** onto the information recording medium **8201**, well-known write-back method is used. In this method, when data writing is required, the CPU **8101** stores data to be written into the information recording medium **8201** in the disk cache **8103**. Then, the CPU **8101** writes the data stored in the disk cache **8103** into the information recording medium **8201** when a vacant region is necessary in the disk cache **8103**, when the data is unnecessary in the host system **8100**, or when a certain period of time has elapsed after the data is stored in the disk cache **8103**. Meanwhile, when the read-out of the data is necessary, if data is on the cache the CPU **8101** reads out the data from the disk cache **8103**, and data is not read out from the information recording medium **8201**. If the data which is to be written on an address is on the disk cache, the CPU **8101** writes new data on the disk cache **8103**. Therefore, the number of data writing on the information recording medium **8201** is reduced. Thus, the number of inputs/outputs is reduced and the operation for recording/reproducing of data is performed at a high speed.

When the data writing is unnecessary, the CPU **8101** closes the partition (a). In the closing processing, the CPU **8101** issues an instruction of writing all data on the disk cache **8103** into the partition (a) of the information recording medium **8201** and at the same time, the partition (a) is logically cut off.

Thus, the data recording on the partition (a) of the information recording medium **8201** is carried out only from the opening processing of the partition (a) until the closing processing thereof.

Next, the data read-out of the host system **8100** is described below. When the data read-out from the (b) partition of the information recording medium **8201** is necessary, the CPU **8101** opens the (b) partition in read-only mode. The CPU **8101** reads out management information from the (b) partition of the information recording medium **8201** in the opening processing.

Next, the CPU **8101** reads out data from the (b) partition. In the read-out processing of data, the CPU **8101** reads out data from the (b) partition of the information recording medium **8201** in the magnetic disk device **8200** and issues an instruction of storing the data thus read out in the disk cache **8103** and at the same time, this data is transferred to the main memory **8102**.

When the read-out of data is unnecessary, the CPU **8101** closes the (b) partition. In this closing processing, the CPU **8101** abandons the data on the disk cache **8103** and cuts off the (b) partition logically.

Thus, the reproduction of the data from the (b) partition is performed only from the opening processing of the (b) partition until the closing processing thereof. Any data is not written into the partition which has been opened in read-only mode.

The partition which has been opened is not opened again without being closed or the partition which has been closed is not closed again without being opened.

Let it be supposed that the (a) partition of the information recording medium **8201** is opened in read/write mode and data to be written into the (a) partition exists on the disk cache **8103**. If the power source of the host system **8100** is cut off, the data on the disk cache **8103** is lost and the data to be written is not written into the (a) partition. Therefore, in the (a) partition, an inconsistency occurs in the file system. For example, the inconsistency occurs in the file control information or the difference occurs between the file control information and the actuality of the file.

If the CPU **8101** opens the (a) partition again in read/write mode and writes data thereinto with inconsistency occurring in the file system, a file which already exists may be destroyed. When the CPU **8101** detects the inconsistency of the file management information, the system goes down.

In order to avoid this, the CPU **8101** checks the consistency of the file system generated in each partition of the information recording medium **8201** when the power source is turned on, namely, in boot time. If an inconsistency is detected, the consistency of the file system is corrected. In the file system in which the inconsistency has been corrected thus, an existing file is not destroyed or the system does not go down due to the inconsistency in the file system.

When an optical disk which is a removable information recording medium is used in such a host system, the termination time of input/output in the program and the termina-

tion time of an operation for actual recording data into an information recording medium does not coincide with each other. Therefore, an optical disk may be taken out before the partition is closed, namely, before data on the disk cache is recorded. In particular, a plurality of programs simultaneously run in the UNIX. Therefore, there is a high possibility that the optical disk is taken out before all programs write data into the optical disk.

The inconsistency of the file system exists in the optical disk taken out before all data are written into the disk. Since the optical disk is exchangeable, it may be incorporated in the system or replaced after boot. Therefore, when the optical disk is used in the above system, the consistency is not corrected in boot time even when an inconsistency exists in the file system, and the existing file is broken or a system-down occurs due to the inconsistency of the file system.

When the optical disk is replaced before data on the disk cache is recorded, namely, when the optical disk is taken out and then another optical disk is inserted into, data which should have been already written on the optical disk is written into another optical disk replaced.

In the optical disk, since ROM (read-only memory) disk is used or in the write protect condition by the setting of a write protecting button, there is a case in which data cannot be written. When a user performs a data writing operation into the optical disk, the user does not write data on the optical disk. Therefore, inconsistency occurs between the data in the disk cache **8103** and the data on the optical disk, which may cause a system-down.

Since in a 4.3 BSD UNIX system in particular, a magnetic disk device having physical sector size as 512 B (bytes) is assumed to be an external memory, a data access is performed in units of 512 bytes. For example, in a manual of SunOs 4.0 of Sun Microsystem Corp. which is a representative manufacturer of a UNIX work stations, the sector size is 512 B in the item of System & Network Administration.

The optical disk is usually provided with a guide track which can be optically detected so that laser beams are irradiated on a recording layer of the guide track and a change which can be optically detected is made to record information. In a general optical disk to be used for processing information, a track formed on the optical disk is divided into a plurality of sectors of a fixed length so that information is recorded and reproduced on a sector by sector basis. In the process of manufacturing such an optical disk, simultaneously with the formation of a guide track, address information showing the position of a sector on the disk is formed for every constant interval. That is, in the process of manufacturing the optical disk, the size of the sector is physically determined. In ISO two kinds of formats of 512 B and 1024 B are determined as the format of the optical disk having a diameter of 130 mm. In the optical disk, in order to secure reliability, data is recorded with an error correcting code so as to correct an error and reproduce data. Since the error correcting code is formed with one sector being a unit, an error is corrected on a sector by sector basis. Therefore, in the case of an optical disk having a sector size of 1024 B, data cannot be recorded or reproduced with 512 B being a unit.

However, in an optical disk having a sector size as 1024 B, compared with an optical disk having a sector size as 512 B, smaller number of control information such as address suffices on a disk. Therefore, more user data can be recorded. As such, under a system in which UNIX is an OS, there is a demand of using an optical disk having a sector size of 1024 B.

But as described previously, an optical disk in which sector size is 1024 B cannot be used under UNIX which performs a data access on 512 B.

SUMMARY OF THE INVENTION

Accordingly, an essential object of the present invention is to provide a method for recording/reproducing information by safely using an optical disk having a sector size of 1024 bytes and serving as a removable information recording medium under the use of UNIX operating system, and an apparatus for carrying out the method.

In a data reproducing operation, the method according to the present invention calculates the position of a sector corresponding to reproducing data existing on the information recording medium, reads all data of this sector into a converting buffer memory, calculates the position of data existing on the converting buffer memory and requested by a host system, and transfers data from the converting buffer memory to the host system with the position of the data thus calculated in response to the request made by the host system.

In a data recording operation, the method according to the present invention calculates the position of a sector of the information recording medium into which recording data is to be written. If the front of the recording data is not at the front of the sector, the sector is read out to be stored in the front of the converting buffer memory. If the end of the recording data is not at the final position of the sector, the sector is read out to be stored in the end of the converting buffer memory and the recording data is overwritten into the converting buffer memory from a position obtained by adding an offset corresponding to data existing in the range from the front of the sector to the front of the recording data to write the data on the converting buffer memory into the information recording medium.

In accordance with the above-described method, in the data reproducing operation, data read out from the information recording medium is stored in the converting buffer memory and a necessary portion of the data is transferred as reproducing data. In the data recording operation, data is read out from the information recording medium as necessary into the converting buffer memory and the data read out thus is written into the information recording medium with the recording data overwritten on the data read out. Thus, under a UNIX which executes a data access in units of 512 bytes, an optical disk having a sector size of 1024 bytes can be used by the use of the converting buffer memory which makes a conversion of the sector size.

According to the present invention, in order to safely use the optical disk serving as a removable medium, the following processing for controlling the medium is executed under UNIX which writes data according to write-back method.

The apparatus according to the present invention comprises an open table corresponding to the "open" state of each partition of the optical disk. The removal of the optical disk from the optical disk device is prohibited when any of partitions of the open table is in "open" state and permitted when all the partitions are in "closed" state. Thus, the optical disk can be taken out from the optical disk device only in the state where data has been correctly written.

According to the present invention, optical disks having different disk identification information are used to read out disk identification information from each optical disk for detecting a possibility that the optical disk has been

replaced. Then, it is decided whether or not the disk identification information thus read out is the same as information read when the partition has been opened. If both are the same, the removal of the optical disk from the optical disk device is prohibited. If both are different from each other, a data input to a replaced optical disk and a data output therefrom are prohibited. Thus, even though the optical disk device in use is reset and the optical disk becomes able to be taken out therefrom, processing continues by prohibiting the take-out of the optical disk again. In addition, even though the optical disk is forcibly replaced during its use, the data of the replaced optical disk is not destroyed.

Further, according to the present invention, the apparatus comprises an open flag, provided on the optical disk, corresponding to the use situation of each partition. The open flag is set to "in use" when the partition is opened in read/write mode and "non-use" when the partition is closed. If the open flag is in the state of "in use" in opening the partition again in read/write mode, the processing for opening the partition is decided as being unsuccessful. Since data is not written into a partition having an inconsistency in the file system due to the take-out of the optical disk during its use, an existing file is not destroyed or the system does not go down.

According to the method of the present invention, the processing for opening the partition is decided as being unsuccessful if it is detected that data writing into the optical disk is impossible. Since processing for writing data into an information recording medium is not erroneously executed, an inconsistency between data on the information recording medium and data on the disk cache does not occur. Thus, the system does not go down.

As described above, according to the present invention, the removable optical disk serving as the information recording medium can be safely used under the UNIX.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, in which:

FIG. **1** is a block diagram showing an apparatus for recording/reproducing information according to an embodiment of the present invention;

FIGS. **2A** and **2B** are flowcharts showing the flow of processing for converting a sector size in a method for recording/reproducing information according to an embodiment of the present invention;

FIGS. **3A**(*a–d*) and **3B**(*a–d*) are content views of a converting buffer memory according to an embodiment of the present invention;

FIG. **4** is a region view on an optical disk according to an embodiment of the present invention;

FIGS. **5A–5D** are flowcharts showing the flow of processing for controlling a removable medium in the method for recording/reproducing information according to an embodiment of the present invention;

FIG. **6**(*a–g*) is a content view showing an open table according to an embodiment of the present invention;

FIG. **7**(*a–g*) is a content view showing an open flag table according to an embodiment of the present invention; and

FIG. **8** is a block diagram showing a conventional apparatus for recording/reproducing information.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

There is shown in FIG. **1** which is a block diagram of an information recording/reproducing apparatus using an optical disk according to an embodiment of the present invention. A host system **1100** and an optical disk device **1200** serving as an external memory are connected with each other via an SCSI bus (Small Computer System Interface) **1300**.

The host system **1100** uses UNIX which performs a data access in units of 512 B (bytes) as an operating system. The host system **1100** comprises a CPU **1101**, a main memory **1102**, a disk cache **1103**, an interface circuit **1104**, a converting buffer memory **1105**, a disk label storing memory **1106**, a disk state register **1107**, an open table **1108**, and an access prohibiting flag **1109**.

The main memory **1102** stores a plurality of programs and data. The CPU **1101** reads out data and programs stored in the main memory **1102** into execution. The UNIX has a data access to the main memory **1102** and the disk cache **1103**. The disk cache **1103** is a memory for performing an input/output processing between the host system **1100** and an external memory at a high speed. The interface circuit **1104** is a circuit for connecting the host system **1100** to the SCSI bus **1300**. The converting buffer memory **1105** is a work memory for converting a data access in units of 512 bytes demanded by the UNIX into units of sector size of 1024 bytes of an optical disk **1201**. The disk label storing memory **1106** stores a disk label read out from the optical disk **1201**. The disk label is described later. The disk state register **1107** is a register for storing the medium type of the optical disk **1201** and a write inhibition state of data set by means of a write protecting button. The open table **1108** holds the open state of each partition of the optical disk **1201**. Each partition takes a value of "open" or "close". The access prohibiting flag **1109** keeping the prohibition state of a data input to the optical disk **1201** and a data output therefrom, thus taking a value of either "access prohibition" or "access permission".

The optical disk device **1200** accommodates the optical disk **1201** serving as an information recording medium. The optical disk device **1200** is provided with an SCSI serving as an interface, thus recording data into the optical disk **1201** and reproducing data therefrom, reporting the type of the optical disk **1201** and the protection state, prohibiting and permitting the removal of the optical disk **1201** from the optical disk device **1200** by means of an SCSI command. In addition, the optical disk device **1200** reports the Unit Attention state to the host system **1100** when the optical device is reset by the turn-on of the power source and the optical disk is inserted thereinto. The optical disk **1201** is accommodated in a cartridge (not shown) and a user can prohibit the writing of data to the optical disk by means of a write protection button (not shown) provided on the cartridge. The optical disk **1201** is logically divided into a plurality (three) of partitions, namely, an (a) partition, a (b) partition, and a (c) partition. A file system is constructed in each partition. The sector size of the optical disk **1201** is 1024 bytes.

The present invention using the optical disk having a sector of 1024 bytes under the UNIX in which a data access is executed in units of 512 bytes is described below with reference to FIGS. **2** and **3**.

FIGS. **2A** and **2B** are flowcharts showing the flow of processing for converting a sector size in the method for

recording/reproducing information according to this embodiment.

FIGS. 3A and 3B are content views of the converting buffer memory **1105** for describing the embodiment. FIG. 3A shows the content of the converting buffer memory **1105** in a data read-out. FIG. 3B shows the content of the converting buffer memory **1105** in a data writing.

A sector in the information recording medium, the sector size of which is 512 bytes is called a logical sector; the address of the sector is called a logical address; the address of the front sector of data is called a front logical address; the address of the last sector of the data is called a final logical address; and the number of sectors in which data exist is called the number of logical sectors. The sector in information recording medium, the sector size of which is 1024 bytes is called a physical sector; the address of the sector is called a physical address; the address of the front sector of data is called a front physical address; the address of the last sector of the data is called a final physical address; and the number of sectors in which data exist is called the number of physical sectors.

In this embodiment, the addresses of all sectors and the address of the buffer memory are integers starting from "0", and the number of logical sectors and the number of physical sectors are integers of "1" or more. The converting buffer memory **1105** has a sufficient memory capacity for storing data to be recorded and reproduced.

The processing to be executed by the CPU **1101** in the case where the host system **1100** reads data from the optical disk **1201** accommodated in the optical disk device **1200** to the disk cache **1103** is described below with reference to FIGS. **1** and **2A**.

Let it be supposed that the read-out of the data of the front logical address (l) and the logical sector number (n) becomes necessary when the host system **1100** is reading out the program from the main memory **1102** into execution. In the UNIX which performs a data access in units of 512 bytes, the data address in the information recording medium is designated by front logical address (l), and the number of blocks in the information recording medium is designated by the logical sector number (n).

The CPU **1101** executes the following processing as shown in FIG. **2A** below in reading out the data of the logical sector number (n) from the front address (l).

(1) Calculation of front physical address (L) from front logical address (l):

If the front logical address (l) is an even number,

$$L=l/2$$

If the front logical address (l) is an odd number,

$$L=(l-1)/2$$

(2) Calculation of physical sector number (N) from logical sector number (n):

If the front logical address (l) is an even number and the logical sector number (n) is an even number,

$$N=n/2$$

If the front logical address (l) is an even number and the logical sector number (n) is an odd number,

$$N=(n+1)/2$$

If the front logical address (l) is an odd number and the logical sector number (n) is an even number,

$$N=(n/2)+1$$

If the front logical address (l) is an odd number and the logical sector number (n) is an odd number,

$$N=(n+1)/2$$

(3) Read-out of data from optical disk **1201** to converting buffer memory **1105**:

The CPU **1101** drives the interface circuit **1104** to output an instruction of reading out the data of the physical sector number (N) from the front physical address (L) to the optical disk device **1200**, reads the data having a capacity corresponding to the physical sector of a physical sector number (N) from the front address (L) of the optical disk **1201**, and stores this data in the converting buffer memory **1105** from "0" address which is the front address thereof.

(4) Transfer of data of converting buffer memory **1105** to disk cache **1103**:

If the front logical address (l) is an even number, the CPU **1101** transfers data having a capacity corresponding to the logical sectors of the logical sector number (n) from the front address of the converting buffer memory **1105** to the disk cache **1103**.

If the front logical address is an odd number, the CPU **1101** transfers data having a capacity corresponding to the logical sectors of the logical sector number (n) from "512" address of the converting buffer memory **1105** to the disk cache **1103**. "512" address is an address obtained by adding an offset corresponding to the capacity of one logical sector to the front address.

Then, the CPU **1101** transfers the data of the disk cache **1103** to the main memory **1102**.

The content of data to be stored in the converting buffer memory **1105** in the data read-out from the optical disk **1201** is described below.

If the front logical address (l) and the logical sector number (n) are both even numbers, data is stored in the converting buffer memory **1105** as shown in FIG. 3A (*a*).

Data having a capacity corresponding to the physical sectors of the physical sector number (N) read from the front physical address (L) of the optical disk **1201** is stored in the converting buffer memory **1105** from "0" address thereof. All data stored thus are transferred from "0" address of the converting buffer memory **1105** to the disk cache **1103** as the data of the front logical address (l) and the logical sector number (n).

If the front logical address (l) is an even number and the logical sector number (n) are an odd number, data is stored in the converting buffer memory **1105** as shown in FIG. **3A** (*b*).

Data having a capacity corresponding to the physical sector of the physical sector number (N) read from the front physical address (L) of the optical disk **1201** is stored in the converting buffer memory **1105** from the front "0" address thereof. Of the data stored thus, only data having a capacity corresponding to the logical sectors of the logical sector number (n) is transferred from "0" address of the converting buffer memory **1105** to the disk cache **1103** as the data of the front logical address (l) and the logical sector number (n).

If the front logical address (l) is an odd number and the logical sector number (n) is an even number, data is stored in the converting buffer memory **1105** as shown in FIG. **3A** (*c*).

Data having a capacity corresponding to the physical sectors of the physical sector number (N) read from the front physical address (L) of the optical disk **1201** is stored in the converting buffer memory **1105** from the front "0" address thereof. Of data stored thus, data having a capacity corresponding to the logical sectors of the logical sector number

(n) is transferred from "512" address of the converting buffer memory **1105** to the disk cache **1103** as the data of the front logical address (l) and the logical sector number (n). "512" address is obtained by adding an offset corresponding to a capacity of one logical sector to "0" address.

If the front logical address (l) and the logical sector number (n) are both odd numbers, data is stored in the converting buffer memory **1105** as shown in FIG. 3A (*d*).

Data having a capacity corresponding to the physical sectors of the physical sector number (N) read from the front physical address (L) of the optical disk **1201** is stored in the converting buffer memory **1105** from "0" address thereof. Of stored data, data having a capacity corresponding to the logical sectors of the logical sector number (n) are transferred from "512" address to the disk cache **1103** as the data of the front logical address (l) and the logical sector number (n). "512" address is obtained by adding an offset corresponding to a capacity of one logical sector to "0" address.

As described above, according to the present invention, a request for reading out data is converted, the data is read out from the optical disk **1201** to the converting buffer memory, and only a necessary portion of read-out data is transferred to the disk cache **1103**. Thus, the optical disk **1201**, the sector size of which is 1024 bytes can be used in the operating system in which data is read out in units of 512 bytes.

Next, the processing to be executed by the CPU **1101** when the host system **1100** writes the data of the disk cache **1103** into the optical disk **1201** is described with reference to FIGS. **1** and **2B**. The embodiment to be described below is applied to the case in which the optical disk **1201** is an information recording medium in which data can be overwritten.

Let it be supposed that the writing of the data of the front logical address (l) and the logical sector number (n) becomes necessary when the host system **1100** is reading out the program from the main memory **1102** into execution.

First, the CPU **1101** transfers the data to be written into the main memory **1102** to the disk cache **1103**. In the UNIX which executes a data access in units of 512 bytes, the data address to be written into the information recording medium is designated by front logical address (l) and the number of blocks in the information recording medium is designated by the logical sector number (n).

In writing data, the CPU **1101** executes the following processing as shown in FIG. **2B**.

(1) Calculation of front physical address (L) from front logical address (l):

If the front logical address (l) is an even number,

$$L=l/2$$

If the front logical address (l) is an odd number,

$$L=(l-1)/2$$

(2) Data read-out of front physical address (L) from optical disk **1201** when front logical address (l) is an odd number:

The CPU **1101** drives the interface circuit **1104** and outputs an instruction of reading out data of one sector from the front physical address (L) to the optical disk device **1200**, reads the data of one physical sector from the front physical address (L) of the optical disk **1201**, and stores this data in the converting buffer memory **1105** from "0" address thereof.

(3) Calculation of physical sector number (N) from logical sector number (n):

If the front logical address (l) and the logical sector number (n) are both even numbers;

$$N=n/2$$

If the front logical address (l) is an even number and the logical sector number (n) is an odd number;

$$N=(n+1)/2$$

If the front logical address (l) is an odd number and the logical sector number (n) is an even number;

$$N=(n/2)+1$$

If the front logical address (l) and the logical sector number (n) are both odd numbers;

$$N=(n+1)/2$$

(4) Calculation of final logical address (m) and final physical address (M):

The final logical address (m) is calculated as follows from the front logical address (l) and logical sector number (n):

$$m=l+n-1$$

If the final logical address (m) is an even number, the final physical address (M) is:

$$M=m/2$$

(5) Read-out of sectors of final physical address (M) from optical disk **1201** to sector when final logical address (m) is an even number:

If the final logical address (m) is an even number, first, an address (X) of the converting buffer memory **1105** in which the final physical sector is to be stored is calculated as follows based on the physical sector number (N):

$$X=1024\times(N-1)$$

Next, an instruction of reading out the data of one sector from the final physical address (M) is outputted to the optical disk device **1200**, data of one physical sector is read from the final physical address (M) of the optical disk **1201**, and this data is stored in the converting buffer memory **1105** from the address (X) in which the final logical sector is to be stored.

(6) Overwriting of data of disk cache **1103**:

The CPU overwrites the date to be written from the disk cache **1103** into the converting buffer memory **1105**. If data exists on the converting buffer memory **1105** at this time, data is overwritten.

If the front logical address (l) is an even number, data having a capacity corresponding to the logical sector of the logical sector number (n) is written in the converting buffer memory **1105** from the front address thereof.

If the front logical address (l) is an odd number, data having a capacity corresponding to the logical sector of the logical sector number (n) is written in the converting buffer memory **1105** from "512" address thereof. "512" address is obtained by adding an offset corresponding to a capacity of one logical sector to "0" address.

(7) writing of data of converting buffer memory **1105** into optical disk **1201**:

The CPU **1101** drives the interface circuit **1104** to output an instruction of writing data of the physical sector number (N) from the front physical address (L) to the optical disk device **1200** and transfers the data having a capacity corresponding to the physical sectors of the physical sector number (N) from "0" address of the converting buffer memory **1105** to the optical disk device **1200**. In the optical disk device **1200**, this data is written into the optical disk **1201** in the order from the front physical address (L) thereof.

The content of data to be stored in the converting buffer memory **1105** in reading out data from the optical disk **1201** is described below.

If the front logical address (l) and the logical sector number (n) are both even numbers, data is stored in the converting buffer memory **1105** as shown in FIG. **3B** (*a*).

Data of the front logical address (l) and the logical sector number (n) transferred from the disk cache **1103** is stored in the converting buffer memory **1105** in the order from "0" address thereof. Data having a capacity corresponding to the physical sector of the physical sector number (N) is written into the optical disk **1201** in the order from the front physical address (L).

If the front logical address (l) is an even number and the logical sector number (n) is an odd number, data is stored in the converting buffer memory **1105** as shown in FIG. **3B** (*b*).

Since the final logical address (m) is an even number, data of the physical sector of the final physical address (M) of the optical disk **1201** is read into the converting buffer memory **1105** in the order from the (X) address thereof. Then, data of the front logical address (l) and the logical sector number (n) transferred from the disk cache **1103** is stored in the converting buffer memory **1105** from "0" address thereof. At this time, the front half of 512 bytes of the data of the final physical address (M) already read is overwritten. Stored data corresponding to the physical sector number (N) is written into the optical disk **1201** from the front physical address (L) thereof.

If the front logical address (l) is an odd number and the logical sector number (n) is an even number, data is stored in the converting buffer memory **1105** as shown in FIG. **3B** (*c*).

The data of the physical sector of the front physical address (L) of the optical disk **1201** is read into the converting buffer memory **1105** from "0" address thereof. Since the final logical address (m) is an even number, the data of the physical sector of the final physical address (M) of the optical disk **1201** is read into the converting buffer memory **1105** in the order from (X) address thereof. Thereafter, the front logical address (l) and the data of the logical sector number (n) transferred from the converting buffer memory **1105** are stored in "512" address thereof. At this time, the 512 bytes of the second half of the data of the front physical address (L) and 512 bytes of the first half of the data of the final physical address (M) already read are overwritten. All stored data of a capacity corresponding to the physical sector number (N) are written into the optical disk **1201** in the order from the front physical address (L).

If the front logical address (l) and the logical sector number (n) are both odd numbers, data is stored in the converting buffer memory **1105** as shown in FIG. **3B** (*d*).

The data of the physical sector of the front physical address (L) of the optical disk **1201** is read into the converting buffer memory **1105** from "0" address thereof. In addition, the front logical address (l) and the data of the logical sector number (n) transferred from the disk cache **1103** are stored in the converting buffer memory **1105** in the order from "512" address thereof. At this time, 512 bytes of the second half of the data of the front physical address already read (L) are overwritten. All stored data of a capacity corresponding to the physical sector number (N) are written into the optical disk **1201** in the order from the front physical address (L).

As described above, according to the present invention, a request for data writing is converted, data is read from the optical disk **1201** into the converting buffer memory **1105** as necessary, data transferred from the disk cache **1103** is overwritten on data written into the converting buffer memory **1105**, and the data on the converting buffer memory **1105** is written into the optical disk **1201**. Thus, it is possible to use the optical disk **1201** having a sector size of 1024 bytes under an operating system in which data is written in units of 512 bytes.

According to the embodiment, the optical disk having the sector size of 1024 bytes can be used without damaging its capacity under the UNIX making a data access in units of 512 bytes.

The above description is concerned with the recording and reproduction of information with respect to an optical disk, but the present invention can be applied to an information recording medium other than the optical disk having a unit of recording and reproducing fixed data.

The present invention for safely using the optical disk which is a removable information recording medium under the UNIX which writes data in write-back method is described with reference to FIGS. **4**, **5**, **6**, and **7**.

FIG. **4** shows respective regions of the optical disk **1201** according to an embodiment of the present invention. The optical disk **1201** is divided into a disk label **4000**, an (a) partition **4100**, a (b) partition **4200**, and a (c) partition **4300**. The disk label **4000** comprises a disk identification information **4010**, a UNIX control information **4020**, and an open flag table **4030**. The disk identification information **4010** is information for discriminating one optical disk from the other. When the construction of the UNIX is formed on an optical disk, a user allots a different value to the disk identification information **4010** for each optical disk. The UNIX control information **4020** includes information necessary for the UNIX to manage the optical disk **1201** such as information showing the position and size of each partition, a bit map showing the use state of each partition and the like. The open flag table **4030** comprises open flags **4031**, **4032**, and **4033** of each partition (a), (b), and (c). Each open flag takes a value either "in use" or "non-use".

FIGS. **5A**, **5B**, **5C**, and **5D** are flowcharts showing the flow of processing in controlling a removable medium according to the method for recording/reproducing information of the present invention.

FIG. **5A** shows the flow of a control to be made when a partition is opening.

At step **5100**, the CPU **1101** starts open processing according to the necessity of a data input to a partition and a data output therefrom. At step **5101**, the CPU **1101** reads out the disk label **4000** from the optical disk **1201** and stores it in the disk label storing memory **1106**. Then, at step **5102**, the CPU **1101** obtains the UNIX control information **4020** from the disk label **4000**. At step **5103**, the CPU **1101** decides the mode of "open" of the relevant partition.

If it is decided that the mode of "open" is read-only, the CPU **1101** decides as to the condition of each partition of the open table **1108** at step **5108**. The CPU **1101** prohibits the removal of the optical disk **1201** from the optical disk device **1200** only when all the partitions of the open table **1108** is "close" state at step **5109** and sets the state of the relevant partition of the open table **1108** to "open" at step **5110**, and the CPU **1101** terminates the processing at step **5111** normally, i.e., "open" has succeeded.

If it is decided at step **5103** that "open" is in read/write mode, the CPU **1101** decides as to the type of the medium of the optical disk **1201** at step **5104**. If the optical disk **1201** is an ROM medium, the CPU **1101** outputs an error message "Read-only file system" at step **5113**, and at step **5114**, the CPU **1101** terminates the processing as abnormal, i.e., "open" is unsuccessful.

If it is decided at step **5104** that the optical disk **1201** is a medium into which data can be written, the CPU **1101** decides as to the set state of the write protecting button at step **5105**. If the write protecting button is set on the write inhibition side, the CPU CPU **1101** outputs an error message "Read-only file system" at step **5113**, thus terminating the processing as abnormal at step **5114**, i.e., "open" is unsuccessful.

If the write protecting button is set on the write permission side, the CPU **1101** decides as to the state of the open flag of the relevant partition at step **5106**. If the open flag of the relevant partition takes a value "in use", the CPU **1101** outputs an error message "Data inconsistency in partition ? (? means a relevant partition)" at step **5112**, and outputs another error message "Read-only file system" at step **5113**, thus terminating the processing as abnormal at step **5114**, i.e., "open" is unsuccessful.

If it is decided at step **5106** that the open flag takes a value "non-use", the CPU **1101** sets the open flag of the relevant partition of the optical disk **1201** to "in use" at step **5107**. Then, the CPU **1101** decides as to the state of each partition of the open table **1108** at step **5108**. If each partition of the open table **1108** is in "close" state, the CPU **1101** inhibits the removal of the optical disk **1201** from the optical disk device **1200** at step **5109** and sets the state of the relevant partition of the open table **1108** to "open" at step **5110**, thus terminating the processing as normal at step **5111**, i.e., "open" is successful.

FIG. **5B** shows the flow of the control when the CPU **1101** has detected that there is a possibility of replacing the optical disk **1201**.

When the CPU **1101** has detected that there is a possibility of replacing the optical disk **1201** due to the turn-on of the power supply and so on, it starts control processing of replacing the disk at step **5200**. The CPU **1101** decides as to the state of the open table **1108**. If the state of all partitions of the open table **1108** is "close", the CPU **1101** terminates the processing at step **5206**.

If the state of any one of the partitions of the open table **1108** is "open", the CPU **1101** reads out the disk label **4000** from the optical disk **1201** at step **5202**. Then, the CPU **1101** compares with each other the disk identification information **4010** of the disk label **4000** thus read out and the disk identification information of the disk label already stored in the disk label storing memory **1106** at step **5203**. If it is decided that the former is the same as the latter, the CPU **1101** issues an instruction of inhibiting the removal of the optical disk **1201** from the optical disk device **1200**. If it is decided that the former is not the latter, the CPU **1101** sets the access prohibiting flag **1109** to "access prohibition" at step **5205**. Then, the CPU **1101** does not communicate with the optical disk **1201** until the access prohibiting flag **1109** is released. Thus, the CPU **1101** terminates the processing for controlling the replacement of the disk at step **5206**.

FIG. **5C** shows the flow of the control to be made when the partition is "closing".

The CPU **1101** starts close processing at step **5300** when a data input to the relevant partition and a data output therefrom become unnecessary. First, the CPU **1101** decides as to the state of the access prohibiting flag **1109** at step **5301**. When the access prohibiting flag **1109** is set to "access prohibition", the CPU **1101** sets the state of the relevant partition of the open table **1108** to "close" at step **5305**. Then, at step **5306**, the CPU **1101** decides as to the state of each partition of the open table **1108**. If it is decided that the state of each partition of the open table **1108** is "close", the CPU **1101** permits the removal of the optical disk **1201** from the optical disk device **1200** at step **5307**. Then, at step **5308**, the CPU **1101** sets the state of the access prohibiting flag **1109** to "access permission". At step **5308**, the CPU **1101** sets the state of the access prohibiting flag **1109** to "access permission". If the access prohibiting flag **1109** is already in the state of "access permission", the processing executed at step **5308** has no particular meaning. Thus, the CPU **1101** terminates the close processing at step **5309**.

If it is decided at step **5301** that the access prohibiting flag **1109** is set to "access permission", the CPU **1101** writes data into the optical disk **1201** at step **5302** if this data to be written into the relevant partition is on the disk cache **1103**. If the relevant partition is opened in read-only mode, there is no data to be written to the optical disk **1201**. Therefore, this processing is skipped. At step **5303**, the CPU **1101** decides as to the mode of "open". Only when the relevant partition is opened in read/write mode, the CPU **1101** sets the open flag of the relevant partition of the disk label to the state of "non-use" and writes data into the disk label **4000** of the optical disk **1201** at step **5304**.

Then, the CPU **1101** sets the state of the relevant partition of the open table **1108** to "close" at step **5305**. The CPU **1101** then decides as to the state of each partition of the open table **1108** at step **5306**. If only all the partitions of the open table **1108** are in the state of "close", the CPU **1101** permits the removal of the optical disk **1201** from the optical disk device **1200** at step **5307**, and sets the state of the access prohibiting flag **1109** to "access permission" at step **5308**. Then, the CPU **1101** terminates the close processing at step **5309**.

FIG. **5D** shows the flow of the control over the partition in correcting the inconsistency of the file system.

On receipt of an instruction from a user, the CPU **1101** starts the processing for correcting the inconsistency of the file system at step **5400**. The CPU **1101** reads out the disk label **4000** from the optical disk **1201**, stores it in the main memory **1102** at step **5401**, and obtains the UNIX control information **4020** from the disk label **4000** at step **5402**.

Then, the CPU **1101** reads out the control information of the file system from the relevant partition of the optical disk **1201** to investigate if there is inconsistency. If there is inconsistency, the CPU **1101** corrects the inconsistency. At step **5404**, the CPU **1101** decides as to the state of the open flag of the relevant partition of the disk label **4000** stored in the main memory **1102**. If it is decided that the open flag is set to "in use", the CPU **1101** sets the open flag of the relevant partition of the disk label **4000** stored in the main memory **1102** to "non-use" and writes it into the optical disk **1201** at step **5405**, thus terminating the processing at step **5406**. If it is decided that the open flag is set to "non-use", the CPU **1101** terminates the processing at step **5406**.

An embodiment is described below more specifically by way of examples of operation. FIG. **6** shows the content of the open table **1108** according to an embodiment of the present invention. FIG. **7** shows the content of the open flag table **4030** according to an embodiment of the present invention. The conversion processing of sector size previously described is always executed in the input/output of data. But the description of the conversion processing of sector size is omitted.

Description is made below by way of an example in which the optical disk **1201** is a writable information recording medium and the write protecting button is set on the writable side.

First, in the host system **1100**, none of the partitions are used. As shown in FIG. **6** (*a*), the states of all the partitions of the open table **1108** are "close". As shown in FIG. **7** (*a*), all the partitions of the open flag table **4030** are "non-use". The access prohibiting flag **1109** is set to the state of "access permission".

First, the partition to be used is opened.

Let it be supposed that the writing of data into the (a) partition **4100** of the optical disk **1201** is necessary when the CPU **1101** is reading out the program from the main memory **1102** into execution. The CPU **1101** starts the open processing in the read/write mode of the (a) partition at step **5100**. The CPU **1101** reads out the disk label **4000** from the optical disk **1201**, stores it in the disk label storing memory **1106** at step **5101**, and obtains the UNIX control information **4020** from the disk label **4000**.

Since the partition is opened at step **5103** in the read/write mode, the CPU **1101** decides as to the type of the medium of the optical disk **1201** at step **5104**. The CPU **1101** issues a Mode Sense command of SCSI to the optical disk device **1200** via the interface circuit **1104**. In response to the command, the optical disk device **1200** produces data including the set state of the write protecting button of the optical disk **1201** and the type of the medium of the optical disk **1201**, thus transferring the data to the host system **1100**. The CPU **1101** stores this data in the disk state register **1107** and takes out the type of the medium from this data.

Since the optical disk **1201** is a writable medium, the CPU **1101** decides as to the set state of the write protecting button at step **5105**. The **1101** takes out the set state of the write protecting button from the disk state register **1107**.

Since the write protecting button is set on the writable side, the CPU **1101** decides as to the state of the open flag **4031** of the (a) partition at step **5106**. The CPU **1101** takes out the open flag **4031** of the (a) partition from the disk label storing memory **1106** storing the disk label **4000**.

The open flag table **4030** is as shown in FIG. **7**(*a*) and the open flag **4031** of the (a) partition is set to "non-use", so that the CPU **1101** sets the open flag **4031** of the (a) partition on the optical disk **1201** to "in use" at step **5107**. The CPU **1011** sets the open flag **4031** of the (a) partition of the disk label **4000** stored in the disk label storing memory **1106** to "in use" and writes it into the optical disk **1201** as recording data. At this time, the open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*b*).

Then, the CPU **1101** decides as to the state of each partition of the open table **1108** at step **5108**. Since the states of all the partitions are in the state of "close" as shown in FIG. **6**(*a*), the CPU **1101** prohibits the removal of the optical disk **1201** from the optical disk device **1200** at step **5109**. More specifically, the CPU **1101** issues a Prevent Medium Removal command of SCSI to the optical disk device **1200** via the interface circuit **1104**. In response to this command, the optical disk device **1200** prohibits the removal of the optical disk **1201** from the optical disk device **1200**. The removal prohibition of the optical disk **1201** from the optical disk device **1200** is not released until the optical disk device **1200** receives Allow Medium Removal command of SCSI from the host system or the optical disk device **1200** is reset.

The CPU **1101** sets the state corresponding to the (a) partition **4100** in the open table **1108** to "open" at step **5110** as shown in FIG. **6**(*b*), thus terminating the "open" processing at step **5111**.

Then, the CPU **1101** writes data. The CPU **1101** transfers data from the main memory **1102** to the disk cache **1103**. The CPU **1101** records the data of the disk cache **1103** into the optical disk **1201** of the optical disk device **1200** by using the write-back method. The CPU **1101** transfers data to the disk cache **1103** when a request for the data writing of the program in execution is made, but does not write data into the optical disk **1201**. Data is written into the optical disk **1201** after a certain period of time elapses. The optical disk device **1200** is in the removal prohibition state of the optical disk **1201** at this time, the optical disk **1201** is not removed even though the user makes an erroneous request for the removed of the optical disk **1201** from the optical disk device **1200** to the optical disk device **1200**.

Subsequently, another partition is opened.

Let it be supposed that data writing into the (b) partition **4200** is necessary when the CPU **1101** is reading out another program from the main memory **1102** into execution. The open processing of the (b) partition **4200** is performed similarly to the (a) partition **4100**. The CPU **1101** starts the "open" processing under the read/write mode of the (b) partition at step **5100**. Then, the CPU **1101** reads out the disk label **4000**, stores it in the disk label storing memory **1106** at step **5101**, obtains the UNIX control information **4020** at step **5102**, decides as to the mode of "open" at step **5103**, makes a decision about the type of the medium at step **5104**, and makes a decision as to the set state of the write protecting button at step **5105**.

Then, the CPU **1101** takes out the open flag **4032** of the (b) partition from the disk label storing memory **1106**, thus deciding as to this state at step **5106**. Since the open flag table **4030** is as shown in FIG. **7**(*b*) and the open flag **4032** of the (b) partition is set to "non-use", the CPU **1101** sets the open flag **4032** of the (b) partition on the optical disk **1201** to "in use" at step **5107**. At this time, the open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*b*).

Then, the CPU **1101** decides as to the state of the open table **1108** at step **5108**. The open table is "open" when the open table has a state corresponding to the (a) partition **4100**. Since the CPU **1101** detects that the optical disk device **1200** is already in the removal prohibition state of the optical disk **1201**, the CPU **1101** sets the state corresponding to the (b) partition **4200** of the open table **1108** to "open" at step **5100**, thus terminating the open processing at step **5111**.

Then, the CPU **1101** transfers data, to be written into the (b) partition, from the main memory **1102** to the disk cache **1103**. At this time, the optical disk **1201** is prohibited from being removed from the optical disk device **1200**.

Next, the (a) partition **4100** is closed. The CPU **1101** starts "close" processing of the (a) partition **4100** at step **5300**. The CPU **1101** makes a decision as to the state of the access prohibiting flag **1109** at step **5301**. Since the access prohibiting flag **1109** is in the state of "access permission", the CPU **1101** writes all data, to be written into the **4100**, into the (a) partition of the optical disk **1201** to be accommodated in the optical disk device **1200** by driving the interface circuit **1104** at step **5302**.

Then, the CPU **1101** makes a decision as to the mode of "open" of the (a) partition **4100**. Since the (a) partition **4100** is opened in the read/write mode, the CPU **1101** sets the open flag **4031** of the (a) partition of the optical disk **1201** to "non-use" at step **5304**. More specifically, the CPU **1101** sets the open flag **4031** of the (a) partition of the disk label **4000** already stored in the disk label storing memory **1106** to "non-use" and writes it into the optical disk **1201** accommodated in the optical disk device **1200** as recording data. At this time, the open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*d*).

Then, the CPU **1101** sets the state of the (a) partition **4100** of the open table **1108** to the state of "close" as shown in FIG. **6**(*d*) at step **5305**. Thereafter, the CPU **1101** makes a decision about the state of each partition of the open table **1108** at step **5306**. Since the state of the (b) partition is "open" and as such "in use" as shown in FIG. **6**(*d*), the CPU **1101** terminates the "close" processing at step **5309**.

The optical disk **1201** is prohibited from being removed from the optical disk device **1200**. Therefore, if the user erroneously makes a request for the removal of the optical disk **1201** to the optical disk device **1200**, the optical disk **1201** is not removed.

Let it be supposed that the user turns off the power source of the optical disk device **1200** and then, turns it on. Since the optical disk device **1200** is reset, the removal prohibition of the optical disk **1201** is released.

Since data to be written exists in the disk cache **1103** for a certain period of time, the CPU **1101** issues a WRITE command of SCSI to the optical disk device **1200** via the interface circuit **1104** in order to write this data into the (b) partition **4200** of the optical disk **1201**. In response to this command, the optical disk device **1200** reports the Unit Attention state by the resetting of the optical disk device **1200** itself. In response to the report, the CPU **1101** of the host system **1100** starts processing for controlling the replacement of the optical disk at step **5200**.

The CPU **1101** makes a decision as to the state of the open table **1108** at step **5201**. Since the open table **1108** has a partition which is not in "close" state as shown in FIG. **6**(*d*) and as such the optical disk **1201** is in use, the CPU **1101** reads out the disk label **4000** from the optical disk **1201** and stores it in the main memory **1102** at step **5202**.

Thereafter, the CPU **1101** compares with each other the disk identification information **4010** of the disk label **4000** read out and disk identification information of the disk label stored in the disk label storing memory **1106** when the (b) partition **4200** is opened in order to decide whether the former is the same as the latter at step **5203**. Since the optical disk **1201** has not been replaced and as such the former is the same as the latter, the CPU **1101** issues to the optical disk device **1200** an instruction indicative of the removal prohibition of the optical disk **1201** at step **5204**. Thus, the CPU **1101** terminates the processing for controlling the disk replacement at step **5206**.

As described above, since the optical disk device **1200** is set again to the removal prohibition state of the optical disk **1201**, the optical disk **1201** is not removal even though the user erroneously makes a request for the removal thereof.

The CPU **1101** writes data into the (b) partition **4200** of the optical disk **1201** after terminating the processing for controlling the disk replacement.

Finally, the (b) partition **4200** is closed. The "close" processing of the (b) partition **4200** is executed similarly to the (a) partition **4100**. The CPU **1101** starts "close" processing upon completion of the program at step **5300**. Subsequently, the CPU **1101** makes a decision as to the state of the access prohibiting flag **1109** at step **5301**, writes data in the disk cache **1103** into the (b) partition **4200** at step **5302**, makes a decision as the mode of "open" of the (b) partition **4200** at step **5303**, and sets the open flag **4032** of the (b) partition to "non-use" at step **5304**. At this time, the open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*e*).

Then, the CPU **1101** sets the state of the (b) partition **4200** of the open table **1108** to "close" at step **5303** and makes a decision as to the state of each partition of the open table **1108** at step **5306**. At this time, all the partitions of the open table **1108** are in "close" state as shown in FIG. **6**(*e*) and therefore, it is understood that none of the partitions of the optical disk **1201** cannot be used. Accordingly, the CPU **1101** issues a command of Allow Medium Removal of SCSI to the optical disk device **1200** to permit the removal of the optical disk **1201** from the optical disk device **1200** at step **5307**. In response to this command, the optical disk device **1200** enables the user to take out the optical disk **1201** thereafter.

Then, the CPU **1101** resets the access prohibiting flag **1109** to "access permission" state at step **5308**, thus terminating the "close" processing at step **5309**.

In this state, the user can take out the optical disk **1201** from the optical disk device **1200**. At this time, all partitions of the optical disk **1201** are closed and all data of the disk cache **1103** have been already written into the optical disk **1201**. Therefore, no problems occur even though the optical disk **1201** is taken out. In addition, if the optical disk **1201** is replaced to another since all the partitions of the optical disk **1201** have been already closed, the data of the previously accommodated optical disk **1201** is not written into the currently accommodated optical disk **1201**.

Data is written again into the (a) partition of the optical disk **1201**.

The (a) partition is opened similarly to the above-described example. When the "open" processing of the (a) partition terminates, the open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*f*). At this time, the state of the open table **1108** is as shown in FIG. **6**(*f*).

The CPU **1101** writes data by using write-back method. The CPU **1101** transfers data to the disk cache **1103** when there is a request for data writing of a program in execution, but does not write data into the optical disk **1201**.

The user turns off the power source of the optical disk device **1200** and then turns it on again. The optical disk device **1200** is reset and the removal prohibition of the optical disk **1201** is released. The user takes out the optical disk **1201** and puts a different optical disk (not shown) into the optical disk device **1200**. At this time, there is data inconsistency in the file system of the (a) partition **4100** of the optical disk **1201** taken out because data which should be written has not been written. The open flag **4031** of the optical disk **1201** remains "in use".

The CPU **1101** issues a Write command of SCSI to the optical disk device **1200** to write data into the (a) partition of the optical disk **1201**. In response to this command, the optical disk device **1200** reports Unit Attention state brought about by resetting. In response to this report, the CPU **1101** starts the processing for controlling a disk replacement at step **5200**.

The CPU **1101** makes a decision as to the state of the open table **1108** at step **5201**. At this time, the open table **1108** has a partition which is not in "close" state as shown in FIG. **6**(*f*) and as such the optical disk **1201** is in use. Therefore, the CPU **1101** reads out the disk label **4000** from the optical disk **1201** and stores it in the main memory **1102** at step **5202**.

The CPU **1101** decides at step **5203** as to whether or not the disk identification information **4010** of the disk label **4000** is the same as the disk identification information of the disk label stored in the disk storing memory **1106**. Since both are different from each other, it is understood that an optical disk accommodated in the optical disk device **1200** is different from the optical disk **1201** which has been already accommodated in the optical disk device **1200**. Therefore, the CPU **1101** sets the access prohibiting flag **1109** to "access prohibition" at step **5205**. Thus, the CPU **1101** terminates the processing for controlling the disk replacement at step **5206**.

The CPU **1101** does not communicate with the optical disk **1201** when the access prohibiting flag **1109** is set to "access prohibition".

Accordingly, even though the optical disk **1201** is forcibly replaced with a different optical disk when the partition of the optical disk **1201** is being used by opening it, the data which should have been written into the previously accommodated optical disk is not written into into the optical disk **1201** accommodated currently.

Finally, the partition used is closed. Upon termination of the program, the CPU **1101** starts the "close" processing of the (a) partition **4100** at step **5300**. Then, the CPU **1101** makes a decision as to the state of the access prohibiting flag **1109** at step **5301**. Since the access prohibiting flag **1109** is set to "access prohibition", the CPU **1101** sets the state of the (a) partition **4100** of the open table **1108** to "close" at step **5305** and makes a decision as to the state of each partition of the open table **1108** at step **5306**. At this time, as shown in FIG. **6**(*g*), all the partitions of the open table **1108** are in "close" state. Then, the CPU **1101** issues an instruction indicating of the removal permission of the optical disk **1201** to the optical disk device **1200** at step **5307**. But since the optical disk device **1200** is already in the removal permission state, this operation has no particular meaning. Then, the CPU **1101** sets the access prohibiting flag **1109** "access permission" at step **5308**, thus terminating the "close" processing at step **5309**.

The case in which the (a) partition **4100** of the optical disk **1201** opened by the host system **1100** and taken out during use is opened again to use it in read/write mode is described below.

The CPU **1101** starts an "open" processing in the read/write mode of the (a) partition **4100** at step **5100**. The CPU **1101** reads out the disk label **4000**, stores it in the disk storing memory **1106** at step **5101**, obtains the UNIX control information **4020** at step **5102**, makes a decision as to the mode of "open" at step **5103**, makes a decision as to the type of the medium at step **5104**, and makes a decision as to the set state of the write protecting button at step **5105**.

Then, the CPU **1101** takes out the open flag **4031** of the (a) partition from the disk storing memory **1106** and decides as to the state thereof at step **5106**. But in this optical disk **1201**, the (a) partition **4100** is not normally closed. Therefore, the open flag **4031** of the (a) partition of the open flag table **4030** remains "in use" as shown in FIG. **7**(*f*). This indicates that the inconsistency of the file system exists in the (a) partition **4100**. Thus, the CPU **1101** indicates error messages of "Data inconsistency in partition A" and "Read-only file system" at steps **5112** and **5113**, thus terminating the "open" processing as abnormal at step **5114**.

Therefore, the (a) partition **4100** with the file system having an inconsistency is not opened in the read/write mode and an existing file is not destroyed or the system does not go down.

Then, the file system of the (a) partition **4100** of the optical disk **1201** is corrected.

The user knows the occurrence of the inconsistency of the file system because of the failure of "open" and upon request from the user, the CPU **1101** executes the program in order to correct the file system.

The CPU **1101** starts the correction processing of the file system at step **5400**. The CPU **1101** reads out the disk label **4000** from the optical disk **1201**, stores it in the disk storing memory **1106** at step **5401**, and obtains the UNIX control information **4020** including the map information of the partition at step **5402**.

Then, the CPU **1101** checks whether or not the file system of the (a) partition **4100** of the optical disk **1201** has inconsistencies. If inconsistencies is detected, the (a) partition **4100** is corrected into a consistent state at step **5403**.

Then, the CPU **1101** decides as to the state of the open flag **4031** of the (a) partition at step **5404**. As shown in FIG. **7**(*f*), since the open flag **4031** of the (a) partition is set to "in use", the CPU **1101** sets the open flag **4031** of the (a) partition of the disk label **4000** stored in the disk storing memory **1106** to "non-use" and writes the disk label **4000** into the optical disk **1201** at step **5405**, thus terminating the processing at step **5406**.

The open flag table **4030** of the optical disk **1201** is as shown in FIG. **7**(*g*) at this time and the open flag **4031** of the (a) partition is set to "non-use". Therefore, the (a) partition **4100** can be used by opening it again in the read/write mode. Since the inconsistency of the file system of the (a) partition **4100** has been already corrected, the existing file is not destroyed or the system does not go down due to the writing of new data.

Next, the case in which the optical disk **1201** is a writable information recording medium and the write protecting button is set on the write prohibiting side is described below.

Let it be supposed that the CPU **1101** is going to write data into the (a) partition **4100**.

The CPU **1101** starts the "open" processing in the read/write mode of the (a) partition **4100** at step **5100**. Then, the CPU **1101** reads out the disk label **4000** and stores it in the disk label storing memory **1106** at step **5101**, obtains the UNIX control information **4020** at step **5102**, and decides as to the mode of "open" at step **5103**. Then, the CPU **1101** decides as to the type of the medium at step **5104**. Since the optical disk **1201** is a writable medium, the CPU **1101** decides as to the set state of the write protecting button at step **5105**. Since the write protecting button is set on the write prohibiting side, the CPU **1101** displays an error message "Read-only file system" to the user at step **5113**, thus terminating the "open" processing as abnormal at step **5114**.

If the optical disk **1201** is an ROM medium and data cannot be written in the above example, the "open" processing is executed as follows: When the CPU **1101** makes a decision as to the type of the medium at step **5104**, and displays an error message "Read-only file system" to the user at step **5113**, thus terminating the "open" processing at step **5114**.

As described above, the partition of the optical disk **1201** into which data cannot be written is not opened in the read/write mode. Therefore, the system does not go due to mismatch between data of the optical disk **1201** and that of the disk cache **1103**.

As apparent from the forgoing description, the removal of the optical disk **1201** from the optical disk device **1200** is controlled according to the open state of the partition, which prevents the destruction of data.

According to the embodiment of the present invention, upon detection of the possibility of the replacement of the optical disk **1201** when the partition has been already opened, whether or not the optical disk **1201** has been replaced is decided by using the disk identification information **4010**. If it is decided that the optical disk **1201** has not been replaced, processing continues with the optical disk **1201** prohibited from being removed from the optical disk device **1200**. If it is decided that the optical disk **1201** has been replaced, an access to the optical disk accommodated in the optical disk device **1200** is prohibited. Thus, when the optical disk device **1200** is reset during use, the removal of the optical disk **1201** is prohibited again to prevent data from being destroyed. If the optical disk **1201** is forcibly replaced, an access to the replaced optical disk **1201** is prohibited to prevent the destruction of the data of the optical disk.

According to the embodiment of the present invention, the open flag of the optical disk **1201** corresponding to the partition is set to "in use" when the partition is opened and the open flag is set to "non-use" when the partition is closed. When the open flag has been set to "in use" when the partition is opened, the partition is prohibited from being

opened in the read/write mode. Thus, even though the optical disk **1201** is forcibly taken out from the optical disk device **1200** during use, data is prevented from being written into a file system having inconsistency. Therefore, existing file is not destroyed or the system does not go down.

Further, the inconsistency of the file system of the partition on the optical disk **1201** taken out during use is corrected and the open flag on the optical disk **1201** is set to "non-use". Thus, the partition is opened again in the read/write mode to safely use the apparatus.

In addition, the partition on the optical disk into which data cannot be written is prohibited from being opened in the read/write mode to prevent the system from going down because of a mismatch between the data on the optical disk and the data on the disk cache.

In the embodiment, the open flag table **4030** is on the disk label **4000**, but an open flag corresponding to each partition can be anywhere on the optical disk except the user's access area.

In the embodiment, the user gives an instruction to the CPU **1101** so that the file system is corrected. In this case, the user is requested to perform an operation so that the inconsistency of the file system is corrected and a possible destruction of data due to turn-off of the power source is warned to the user. It is possible that the CPU **1101** automatically corrects the inconsistency of the file system when it has detected the inconsistency in "open" processing. Thus, the "open" processing can be terminated normally, which eliminates the user's operation.

The information recording/reproducing method and apparatus of the present invention can be applied to an apparatus using a removable information recording medium other than an optical disk in the controlling process.

In addition, the information recording/reproducing method and apparatus of the above-described embodiment of the present invention use a disk cache of write-back system, but the information recording/reproducing method and apparatus in which data writing is executed from "open" process until "close" processing.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

What is claimed is:

1. A method for recording and reproducing information carried out by an apparatus employing an information recording medium having at least one partition composed of a plurality of files and file management information and a flag area in which an open flag is recorded in one-to-one correspondence with each partition, said open flag setting an in-use state in a partition where logically imperfect file management information is recorded and setting a non-use state in a partition where logically perfect file management information is recorded, said method having a partition opening process conducted before the start of a file recording operation and a partition closing process conducted after the completion of the file recording operation,

said partition opening process comprising the steps of:

discriminating the states of the open flags read out from the flag area;

error-terminating said opening process when at least one of the open flags shows the in-use state is detected in said flag discriminating step; and

setting the open flag corresponding to the partition to be subjected to the partition opening process to the in-use state when only the open flag shows the non-use state is detected in said flag discriminating step and recording on said flag area,

said partition closing process comprising the steps of setting the open flag corresponding to the partition to be subjected to the closing process to the non-use state and recording on said flag area.

2. A method as defined in claim **1**, further including a file system restoring process for restoring the file management information in the partition where a logical inconsistency is detected, said file system restoring processing comprising a step of setting the open flag corresponding to the partition where the logic inconsistency is detected to the non-use state and recording on said flag area.

3. An apparatus for recording and reproducing information employing an information recording medium having at least one partition composed of a plurality of files and file management information and a flag area in which an open flag is recorded in one-to-one correspondence with each partition, said open flag setting an in-use state in a partition where logically imperfect file management information is recorded and setting a non-use state in a partition where logically perfect file management information is recorded, said apparatus comprising:

an opening means for conducting the partition opening processing before the start of the file recording and reproducing operation, said partition opening means comprising:

(a) flag discriminating means for discriminating the state of open flags read out from the flag area;

(b) means for error-terminating the partition opening process when said flag discriminating means detects at least one of the open flags showing the in-use state; and

(c) means for setting the open flag corresponding to the partition to be subjected to the partition opening process to the in-use state when said flag discriminating means detects only the open flag showing the non-use state and recording on said flag area; and

a closing means for conducting the partition closing process after completion of the file recording and reproducing operation, said partition closing means comprising:

means for setting the open flag corresponding to the partition to be subjected to the closing process to the non-use state and recording on said flag area.

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